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BATTERY OF TWO 6-INCH COAST DEFENSE RIFLES, MOUNTED UPON DISAPPEARING CARRIAGES.
(Constructed by the Author at the U. S. Military Academy at West Point, 1907.)

MILITARY PREPAREDNESS
AND
THE ENGINEER

A HANDBOOK FOR THE CIVILIAN ENGINEER.

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INTRODUCTION

As a civilian engineer who has in his spare moments devoted considerable study to matters military during the past fifteen years, I cordially recommend this volume to members of the engineering profession who are desirous of rendering the service for which their technical training has laid the foundation.

CORNELIUS VANDERBILT, M. E.
Colonel, 22nd New York Engineers.

PREFACE TO SECOND EDITION.

The purpose of this book is in no way changed by revision. Even with the country at war, there are many engineers who wish to serve but have vague ideas as to the part they may best play.

To those who are equipped for active service with the field forces the Author desires particularly to appeal. It is his aim to present to such men the salient points of military engineering in the language of the civilian engineer.

The new material is compiled from many different sources. Much relating to field fortifications was obtained directly from participants in the European struggle, and is descriptive of types in actual use in this war. Acknowledgment is made to the *U. S. Infantry Journal* for valuable information and suggestions contained in a series of articles on field entrenchments.

Acknowledgment is also made to *Professional Memoirs, Corps of Engineers, U. S. Army,* for data obtained from articles upon the "Consolidation of Captured Points," and "Wire Entanglements," and to a paper by Capt. Burgess, Corps of Engineers, U. S. Army, Engineer School, 1908, upon the duties of Engineer troops. Special indebtedness is acknowledged to Corporal W. W. Daiker, Company F, 22nd N. Y. Engineers, for his excellent drawings.

As this is written the Author's regiment again enters the Federal service. Many civilian engineers are probably taking similar obligations in the various National Guard units throughout the country. The

Author takes this opportunity to express his confidence that these same engineers, who have contributed so largely to the greatness and prosperity of the United States in time of peace, will prove equal to all calls upon their skill in time of war.

New York, July 16, 1917.

AUTHOR'S PREFACE.

The purpose of this book is to place before the Engineers of America as accurate an idea as possible of the opportunities and limitations that will confront the Civilian Engineer in the event of war, to show him what he can do to assist in preparedness against invasion and how he must go about the matter.

Modern War is largely an engineering problem, and for its successful conduct there must be at the service of the country from the first a very large number of engineers with more than an indefinite notion that they are willing to fight, and die if need be, for their country. Many, many more will fight and fewer by far will die, if the engineering profession at large can readily obtain a proper conception of the duties, the responsibilities, and the active functions of the individual engineer, in a few weeks immediately following his call to the colors.

For this reason the Author addressed several large meetings of Engineers belonging to the American Society of Civil Engineers, the Harvard Engineering Society of New York, etc., and what he was able to present on the platform and the screen was so enthusiastically received that he was very ready to acquiesce in the invitation of the Publishers to give the material to the profession at large by broad publication.

The material of the lectures has been carefully revised and very materially enlarged. The book, however, is not a service manual, of which several, admirably prepared by the War Department, are available. It attempts only to fulfill the purpose originally indicated. If this attempt be successful, the Author's obligations and his hopes will have been more than met.

A large part of the technical matter is based upon the

Engineer Field Manual, U. S. Army, and a number of cuts have also been reproduced from the same source. Chapter VI, "Engineer Troops in the Field," is taken almost entirely from an article in the Official Bulletin, General Staff, Vol. 1, No. 4, Dec., 1914. The matter was so important, as giving specifically and in detail the duties of the Engineers under all conditions, that nearly half the original article is here reproduced.

The matter in Chapter V, on rifle instruction, illustrates the methods devised and used by the Author in his own company.

Acknowledgment is made to Prof. Whitaker, of the Department of Engineering Chemistry, Columbia University, for permission to reprint his excellent article on "High Explosives."

New York. February 28, 1916.

CHAPTER I.

INTRODUCTORY.

After two years of agitation for an adequate military preparedness, with war becoming more and more inevitable, the United States at length find themselves drawn into the world conflict with apparently little or nothing accomplished in the way of material preparedness.

It is fortunate indeed that this war finds us with our enemy already engaged to the hilt, separated from us by three thousand miles of ocean, and with the fleets of an allied power intervening. Otherwise we might even now be preparing desperately to meet invasion, our navy dispersed by superior forces and the transports of an expeditionary force approaching our shores.

Such fortune comes to few nations and few times to any one of them. The respite thus gained should be accepted thankfully and utilized to the utmost. We have time indeed, but not time to waste. Our wealth placed at the disposal of our new allies may greatly increase their effectiveness, but it cannot in the end buy for us immunity from the duty of at least preparing to take a more active part in the struggle. The instinct of self-preservation alone should dictate the wisdom of such a course. The conclusion of a separate peace by any one of the allied powers would change materially the aspect of the war, and might eventually place the United States in a position of great danger.

Action, therefore, is urgently demanded, but not action of a hasty or ill-advised character. The "*On*

to Richmond" spirit which drove an unprepared volunteer army to disaster at Bull Run has no place in our present program. Although much remains to be accomplished in the way of military preparedness, there is yet time for preparedness of the right sort, based upon a due appreciation of our needs and of the resources at hand. Those who clamor for immediate action, therefore, should remember that for the first time in its history the Congress of the United States proposes to take counsel of the mistakes of previous wars and to profit by them. For the first time we shall enter a war with our preparations based upon a sound military system, one which is elastic and capable of being expanded sufficiently to bring into play, if necessary, the entire military strength of the nation. From this system may develop what we have always lacked, a permanent military policy which shall guarantee our future safety.

This much, then, may we credit to the campaign for preparedness. Though our actual gain in men and munitions be small, the educational effect has been great, and were this the only effect of the campaign, it might be considered highly successful.

The problem before us, therefore, lies in the supply of large quantities of men and munitions, and the training of these men for the work that lies before them. The manufacture of munitions we may safely leave to those who are specialists at such work, and the matter of raising and organizing our armies may be delegated to Congress and the War Department. In the interval which must elapse before such a force can be raised, however, much may be done by the individual in preparing himself for the part which he is to play.

This discussion shall deal, therefore, with a very small part of the general subject of military preparedness—the part of the engineer as an individual.

If each engineer sees to it that he *personally* is fully prepared to take his place as an officer or non-commissioned officer of engineer troops, then may we be said to have effected a great step towards preparedness. This war is one of engineers, and upon the efficient leadership of our engineer troops will depend in large measure our ultimate success.

The work of the Engineers is divided into two great classes, that in the Zone of the Advance at the front, and that in the Zone of the Line of Communications. In the latter the works are of a more deliberate and permanent character, directly akin to civil works. Skilled civilian labor would be largely used, and civilian Engineers could be taken directly from their daily duties to supervise the construction of highways, railways, bridges, and the more deliberate defensive works for their protection. In this work the civil engineer can find a large sphere of usefulness, the duties differing little from those of his ordinary practice, except that they are directed by officers towards military ends. These men would not necessarily be commissioned, in fact, many of those best qualified would be beyond the age for commissions in the grades corresponding to the work which they would do. Let it be understood, therefore, that the writer considers such service of the highest importance, and that a Technical Reserve of members of the profession at large, immediately available for work of this character upon the outbreak of hostilities would be of great value to the country. In the discussion which follows, therefore, the former class of engineering work only will be considered, that of the Zone of the Advance, where conditions are totally different.

There is work in plenty of both kinds to be done, and one may render equally good service in either class. However, if *all* choose to work in the rear, the troops at the front will be seriously handicapped. Service along

the Line of Communications falls naturally to men of long experience and ripe judgment. That at the front requires men with physical endurance, initiative and enthusiasm, qualities ordinarily possessed in good measure by the younger generation of engineers. It is to these men, therefore, that we must look for engineer officers in our next war. The average engineer faces much preparation before he is qualified to render effective service of this character.

It has been said that the science of Engineering had its beginning when the Missing Link first used a stone to crack a cocoanut. This is probably an error in so far that the stone was used to crack, not the cocoanut, but his neighbor's skull, since it is a pretty well established fact that the first engineers were military engineers. As time went on and civilization developed, engineers were in time of peace used upon public works, and it is only in modern times that the profession of engineering has become a distinct calling. The latter is now so diversified in all its branches that one adopting engineering as a profession must be a specialist. It is beyond the capacity of any man to be qualified in all the subjects that are grouped under the term engineering.

A locating engineer could not be expected to take charge of the electrification of his own railway, and a bridge erector would hardly make a success as master mechanic of the same road; yet each is an engineer, and a railroad engineer at that. Similarly, a successful highway engineer would not be chosen to design a great bridge, nor would an irrigation engineer step into a position in charge of a shield tunneling job, and yet each of these positions calls for a civil engineer.

The military engineer makes use of *all* branches of engineering science but often in a different way and with an entirely different view point than his civilian confrère. His work is destructive as often as construc-

tive, his materials are scarce and of the crudest, and often utterly unfitted for his purpose. Plant is almost unknown, labor is plentiful but often inefficient, time is all-important and there is constant and serious interference by the enemy with each step taken. Everything must be done with a military purpose and from the view point of the military man and until the engineer acquires this point of view he cannot make a success in the field.

It must also be remembered that the military engineer is a soldier before he is an engineer. He commands troops who must be prepared to fight as infantry to protect themselves or their work. He must therefore be versed in the drill regulations and the tactical considerations governing the use of that arm of the service. He must administer the affairs of his command and look after its training, housing, transportation and sanitation. He must understand thoroughly the plain business of "soldiering" with its many details before he begins to think of using his men as engineers.

An officer in the field cannot act in a mere consulting capacity upon purely technical matters. He must be prepared to put his shoulder to the wheel and take his share of the enormous amount of routine and other necessary but uninteresting work with which the time of the military man is filled. Nor is there a place at the front for a specialist. The engineer officer must be qualified to conduct a reconnaissance, locate trenches, supervise their construction and the placing of obstacles, direct siege operations, drive a mine or sap, build roads, railroads or bridges, or use explosives, entirely upon his own responsibility.

Let us consider for a moment that a number of practical engineers have been commissioned in a volunteer reserve and that, war having been declared, one of them receives an order to this effect:

"1. Captain A. is detailed for duty and assigned to the command of Company H, Second Engineers, U. S. Volunteers, mobilized and stationed at Camp Wilson, N. J.

2. Captain A. will make immediate requisition for arms, equipment and engineer property and for transportation to Portville for embarkation with expeditionary forces."

Query: What does he requisition, of whom is it requisitioned, and how much transportation does he request to move his company at war strength and fully equipped?

Again, suppose him arrived in camp, his officers and men, volunteers like himself, just reported. The First Sergeant says, "Captain, the cooks have nothing to cook. No rations have been sent over by the commissary." The Captain hurries to his organization supply officer and complains of this manifest attempt to starve his men. He is told, "Issue call was sounded at ten A. M. and your Quartermaster Sergeant was not present. Furthermore, we have received no ration return from you nor a morning report of your strength."

Query: What is a ration return or a morning report, how do you make them out, and to whom do you send them?

And again, at the front, the brigade commander sends an urgent call to division headquarters for an engineer officer to assist in preparing a position for defense. Captain A. is favorably known to the chief engineer of the division as a capable engineer and one who has studied diligently since being commissioned, so he is sent.

Knowing from his field manual that a good defensive position should afford a clear field of fire to the front, that it should provide concealment and good communications to the rear, with its flanks resting upon impassable objects, Captain A. selects a position forward of

the crest of a slope, lays out complete trenches with overhead cover, sods them over, places entanglements at the foot of the slope, and carries the line from the river bluff on the left to contact with the lines of another brigade on the right. The attack is then awaited in confidence.

But when the men have dug themselves in, a swell in the ground completely blocks off from view the foot of the slope and considerable space in front and rear, and the entanglements, so plainly visible to Captain A. on his horse, are in the middle of a dead zone, to which the enemy advance by rushes, line after line, and destroy the entanglements at their leisure. Spurred on by their officers the men leave their elaborate trenches, advance to where the enemy is visible and open fire from a prone position, only to be driven back by shrapnel from the enemy's artillery, firing over the heads of his own troops. They are followed up the hill by masses of the enemy's infantry, who rush the trench before it can be reoccupied, drive the defenders back in headlong flight, turn the flanks of the adjacent brigade, and the day is lost.

These few instances are not exaggerations. Those who served in the Spanish War can multiply occurrences of the first two kinds and many an officer of more experience than Captain A. has been guilty of the same neglect, of locating trenches without placing his eye at the level of the men who will occupy them.

In recent articles of the technical press it has been urged that practical engineers, contractors' men, construction foremen, etc., were as well or better qualified to perform certain classes of work than regular engineer troops and could be used for this work without further training. This is admitted, but can they outside their special lines perform *all* the duties that fall to the engineers, including *fighting,* as well as troops possessing a more general training? These men have

made the United States famous wherever engineering work is done and their knowledge and experience will be a tower of strength to the army. But consider how much more effective they would be if each were trained as a soldier as well as an engineer; if he possessed a familiarity with the different technical duties of the military engineer *in addition* to his own specialized knowledge.

Let us imagine that all members of the engineering profession who are of military age and physically fit have studied and attended instruction camps, lectures, etc., until they are really fitted to command engineer troops. Does this knowledge on their part tend to lessen the confusion and complications incident to their recruiting, mobilization, mustering into service, commissioning and assignment, taking command and welding their organizations into efficient units? Yet this must be done before they can become efficient officers. If they simply enlist and serve in the ranks their training and talents are in a measure lost by not being fully developed, and we still have the work of bringing them into the service.

There are many who await Congressional action before deciding what they individually will do. It is certain that any measures adopted will take months to carry out, and this time can very profitably be devoted to individual preparedness. For those who wish to improve this time, there is the National Guard, which is a *going concern,* and which is already at work upon the task of training officers and men. That the National Guard has its faults is admitted, but so has the Army: that those of the National Guard are the more serious cannot be denied, but it must be conceded that the result in each case is *due to conscientious effort,* and is probably the best that can be done under the circumstances. Moreover, the faults of the National Guard are due not

so much to inside as to outside causes, not the least of which is the attitude of the general public towards the Guard. We could not have full companies if public sentiment was opposed to enlistment, nor full attendance at maneuver and instruction camps if employers would not let their men off, and we cannot now have the most efficient organizations if the men who can make them so hold back from enlisting.

But in spite of its drawbacks the National Guard can be made a powerful factor in an emergency. These men *are* organized, they *are* under arms, they are equipped *exactly* like the Army, and receive instruction of the *same* character out of the *same* textbooks. The Guard today, faulty as it is, still forms the most practicable, and in fact the *only practicable method* we have of promptly reinforcing the Regular Army in time of national need.

So, therefore, if the engineer expects to volunteer or to qualify for a commission in the Reserve Corps, he may, instead of marking time until all the legislation and plans are complete, improve the time by preparing himself for the position which he may desire to hold. When these forces are organized, in far greater numbers than any which we have called to the colors since the Civil War, the National Guard will be largely drawn upon for officers and non-commissioned officers, and one can certainly lose nothing by advance preparation.

CHAPTER II.

HOW TO OBTAIN A MILITARY TRAINING.

Considerable space has been devoted to showing that the civilian engineer who wishes to become a potential military engineer should first obtain a military training. It is therefore essential that there should be outlined some practical manner in which this training may be obtained.

There are a number of methods which have been suggested, each of which has its advocates, and each of which has its good and bad points. Those which have been most urged are: the Army, college training, home study, instruction camps, and the National Guard.

The Army. Universal training in the Army is objectionable to the people on account of its cost, because many men would be withdrawn yearly from productive pursuits, and because of the fear of all that suggests a military form of government. Its many advantages over the volunteer system in time of war, however, and its absolute fairness to all, in addition to the resulting physical benefit to the youth of the country, argue strongly for its adoption. Once accepted in the exigencies of the present war, it will undoubtedly be retained as a part of our permanent military policy. This system, however, scarcely lies within the scope of the present discussion, which aims simply to point out the manner of utilizing most effectively the facilities that we now have.

For the practicing engineer to serve in the Army in time of peace, in order to obtain the military training necessary to qualify himself for a war commission, is not advisable. The soldier who does his full duty, and learns thoroughly all

the details pertaining to his position, does not qualify himself to become an officer. Even those men who graduate from the ranks into a commission must pursue a course of study entirely outside their ordinary duties as soldiers. An engineer who enlists in the Army, therefore, expecting after a term of service to enter an officers' reserve, will find himself confronted by examination questions upon matters of which he heard nothing as a soldier, no matter how conscientiously he applied himself.

The duties of a soldier are one thing, those of an officer are another, and the difference is great. They do not merge, and proficiency in the lower grade is no guarantee of qualification for the higher.

College Training affords a splendid opportunity if properly conducted. Nearly all the large engineering schools offer facilities for military training, and in the Land Grant Colleges, i. e., those which received grants of public lands for the maintenance of their Agricultural Schools, military training is compulsory. Most schools of this character, where the students drill a certain number of periods each week, and the work is supervised by an officer of the army detailed for that purpose, are rated as Class "B" by the War Department. The students are under no military control outside the drill hour, and the instruction is about on a par with the infantry drill of the better National Guard organizations.

From six years military experience in a typical university of this character, and from considerable information gained by conversations with students of similar institutions the writer can advisedly say that he does not believe that the instruction, as now carried out, offers the proper training to qualify young men for field service as officers of engineers.

The drill comprises infantry tactics and close order formations. There is very little rifle practice, and no

real instruction in the principles of musketry. In winter, when the weather prevents outdoor drill, there is indoor instruction, mostly in the Infantry Drill Regulations. A few advanced students may receive lessons in Minor Tactics and the Art of War, but these are limited to the cadet officers, who have elected to serve for a longer period than the university regulations require. The percentage of the total force which receives other than elementary infantry instruction is therefore very small. Finally, field service is entirely lacking in every case of which the writer has received information.

There are a number of military institutions in the United States which are rated as Class "A" by the War Department, and in which the military instruction is of the highest order, ranking second only to the Military Academy itself. However, these schools are mostly in the preparatory class, and are famous principally on account of their military character. None of them is numbered among our leading technical institutions. Even at West Point the engineering instruction is very limited in its scope, and officers graduating into the Engineers must take a post-graduate course in engineering at the Engineer School at Washington Barracks, D. C.

It seems evident, therefore, that if our engineers are to receive an adequate military education along with their engineering course, the scheme of military instruction must be considerably modified, probably along the following lines:

1. Its scope must be extended, and military instruction required throughout the undergraduate course. As much attention should be paid to work in the class-room as to that on the drill ground, and a regular curriculum should be followed, embracing supply, organization, administration, minor tactics,

field service regulations, field engineering, *and military history.*

2. Less time must be allowed for infantry drill, and the portion which is so occupied must be devoted partly to extended order drills, not on the level campus, but on terrain approximating field conditions.

3. The drills, outside of infantry tactics, should include military topography and sketching, in which the engineer is usually wofully deficient, rifle practice, and the underlying principles of *rifle instruction.*

4. Finally, the student should be required to attend one of the college men's instruction camps held by the War Department. Students from the technical schools could be accommodated in engineer camps, directed by engineer officers of the Army and assisted by engineer troops, similar to the instruction camps of the militia engineers. Such field service would be productive of a much higher efficiency than local encampments, managed entirely by the university authorities.

A man completing such a course should be fully qualified to lead engineer troops in the field, but the mere fact of his having taken the instruction is not conclusive evidence of his qualification. Many men walk through a technical course, receiving a diploma at the end, without being in the least qualified to practice engineering. It is right and proper, therefore, that the War Department should require a qualifying test before admitting a graduate under the system to an officers' reserve.

Nor does the responsibility of the War Department cease here. All this training is in a fair way to be lost to the country if the proper office does not keep in touch with the graduate, send him orders and literature pertaining to his branch of the service, and encourage him to attend further instruction camps or to join the National Guard and pass his training on to others. Above all, there should be required of him, not only his

changes of address, but a periodical report, upon a printed form, which will insure a complete record at all times as to his health, whereabouts and any other data that would affect his availability for prompt service. In turn, the reservist must be notified of the *cadre* or skeleton organization to which he is assigned, and its mobilization point, to prevent confusion upon reporting for duty.

Furthermore, in order to prevent deterioration, and to insure his keeping up with military progress and developments, he should be required to report at certain intervals to be examined for a higher grade. Upon failure to pass this examination, his connection with the reserve should cease. Judging from the busy life of the average engineer several years out of college, how many would remain on the reserve list under these conditions until they reached, say, the grade of captain? And yet these conditions, severe as they seem, are absolutely essential if we desire an officers' reserve capable of rendering *prompt and effective* service when called upon.

This, in the opinion of the writer, is the fatal defect in the system of college training. It is a simple matter to train these men. There is a precedent for each step outlined, and it can all be accomplished without further legislation. The Government requires military training in return for Federal aid to the agricultural schools; then let it specify the character of this training. The War Department has established college men's camps of instruction; then let the technical men be accommodated in an engineering camp. Candidates have been examined and commissioned in the Officers' Reserve Corps; then let the War Department keep in touch with these men, see that they do not backslide and arrange for a system of promotion by examination as in the Army.

Unless such a system is thoroughly carried out, the

whole system fails. We train the men, lose track of them, and never know who or how many can be counted upon in an emergency. Furthermore, a scheme of skeleton units is a prime requisite, if we would avoid the confusion of organization after the beginning of hostilities.

Yet, with all this accomplished, the training, the close contact, and the organization, ready for immediate response to a mobilization order, the whole structure still rests upon the self-discipline and sense of responsibility of the individual engineer, who, busy with making a living and a career for himself, must study privately, keep up with military progress, for the military art makes long strides even in times of peace, and prepare for promotion examinations, merely upon the chance that, sometime, his services may be required.

Moreover, while an improved system of college training may be of great benefit in preparing future generations of engineers for volunteer commissions, it is not available for those who have already completed their college courses and are now engaged in active practice. Many of these are anxious to serve and, properly trained, could render very effective service.

Home Study, amplified by lectures, is the favorite plan of many engineers in this country. The causes of this preference are easily seen:

1. There is no compulsion to take instruction except as desired and as perfectly convenient to the individual.

2. There is no supervision over his work and no test to pass, so he is not bothered with monotonous details, and can study only what interests him.

3. There are no responsibilities, no formations to attend, no duties to perform, and no restraint upon his liberty.

These very reasons are sufficient to condemn the

method so far as any practical benefit is concerned. A man will study only when it pleases him to do so and then only that which interests him, and even a course of reading would find few to follow it conscientiously to the end. There are, furthermore, many things connected with military service that cannot be learned by study alone, as will be seen later.

And how are such men to be made available for service? They apply for commissions upon the outbreak of hostilities, and find that they have no standing with the War Department. They cannot submit a record of any connection with a reputable military organization, nor even a certificate from an examining board. To examine and classify them at this late hour would be impracticable, and the War Department would hesitate long before commissioning a man with absolutely no military experience. The probable reply to such application would be, "Gentlemen, we have a place for you—in the ranks."

Training Camps are a development of the college men's camps which originated in 1913. The few that have been held so far have been eminently successful in imparting to a number of men the rudiments of field training by means of an intensive method, and have aroused great enthusiasm among those attending.

In these camps the men are by degrees accustomed to the long marches and the full pack. The time at their disposal, usually thirty days, easily permits of this, and the results are quite different from those obtained by the average militia organizations on maneuvers of perhaps a week's duration, where the rule is a full pack and usually a march of fair length from the very beginning.

The most famous camp, that of the "First Training Regiment," at Plattsburg, N. Y., attracted a large number of men prominent in various walks of life, and the course of training was carefully laid out to illus-

trate the problems which will confront troops in the field. The success of the camp was largely due to the type of men attending and the intelligence displayed in grasping the principles involved as well as to the tact and hard work of the officer instructors.

After the day's drill it was customary to hold lectures upon military subjects, mostly explanatory of the drills and maneuvers executed during the day.

The attitude of the daily press was probably the one objectionable feature of the encampment. The camp was hailed as the last word in military education, grinding out fully trained officers in thirty days' intensive instruction. That this attitude was not shared by the men themselves nor contemplated by the army officers who were their instructors is easily seen from their writings and public utterances. The above mentioned press items, however, might be productive of much misunderstanding on the part of prospective participants.

It is conceded that a man of natural ability, accustomed to handling men, might learn enough of field conditions at such a camp to carry him successfully through a campaign as a company officer of volunteers. But unless he has had previous military training, it is certain that he must take the field lacking in *some* of the knowledge that an officer should have, and if the exigencies of the campaign do not call for exercise of this knowledge at some critical moment, he is fortunate. For a man who has undergone military training in college, and has had experience as a cadet officer, the training camp would furnish the necessary field service to complete his military education and fit him for a volunteer commission.

That field service alone, however, of limited duration and unsupported by previous training, can fully prepare a man to lead troops in modern warfare, is a pro-

position not to be seriously considered. The following quotations may throw some light upon the subject.

The first is from a circular issued by those in charge of the training camps for the summer of 1916, and shows their view-point as to the scope of the instruction given:

*"The aim is to give men of average physique four or five weeks *a year* of intensive military instruction under officers of the Regular Army, so that at the end of that time men of no previous military experience will, at least, have learned the *rudiments* of military organization and discipline and use of the military rifle, and become *somewhat* familiar with the equipment, feeding and sanitary care of an army in the field, and the handling and control of men in maneuvers."

The second is from an anonymous article reviewed in the *International Military Digest* for February, 1916, and presents the views of a member of the *First Training Regiment* at Plattsburg.

"Note. This is written from the standpoint of a 'rear-rank private' at the recent camp of instruction at Plattsburg, N. Y.

'Our first reflections concerned organization. Here we were, thirteen hundred eager, unskilled men from civil life, parodying what happens when our country goes to war. A miracle of transformation was wrought upon us. In two days we had ceased to be a mob. In a week we had got by the first appalling fatigue. In a fortnight we had developed out of nothing our own noncommissioned officers. Three weeks had made an effective if ragged regiment of us.

" 'It needed little reflection to see that the health, order, and spirit of Plattsburg could never be improvised. These depend upon long founded experience and intelligence. I imagined what would befall us if all the cooks, doctors, officers, and regular

*Italics are the author's.

privates were suddenly withdrawn and the 'Business Men's Regiment' left to its own devices. Even in time of peace the result would be calamitous.

" 'A more ominous reflection came on the first day of combat tactics in open order. Suppose this were not the end of the drill, after two weeks of amateur soldiering, but the beginning of a battle, after two weeks of real war. Who would teach us to shoot twice a minute and to roll over in changing position when to rise were death? Not our present captain and lieutenant, not our smiling and steely-eyed regular sergeant, but just willing duffers like ourselves, fighting by day and learning how to fight out of 'Infantry Drill Regulations' at night. As things go in modern war, should the regular army have to face a powerful foe, there would in a month be no regular army. The funded military intelligence of the nation would be shot to pieces in just about four weeks. The men who could make soldiers out of the million men, who we are assured would spring to arms, would be themselves in soldiers' graves or lying unburied.

" 'To imagine ourselves in any sense protected because the American is a natural fighting man is the last folly.

" 'After a month we could march, camp, shoot, take care of ourselves, maneuver a few hours a day. I think that perhaps a quarter of us had hardened enough to do much more than required of the regiment, but most of us were still far from fit to stand the physical strain of actual warfare. Here is a whole side of preparation for war about which there is the wildest misconception. People cannot realize that a stalwart untrained citizen is no more physically fit to fight than a sturdy untrained freshman is fit to step into a football match.' "

That field training alone is not the best system of developing officers is recognized by the War Depart-

ment in the course of instruction followed at West Point. Instead of living in camp for a year, undergoing intensive training, and then receiving their commissions in the Army, the cadets are given a thorough theoretical course along with their practical work.

The soldier's instruction comprises rifle shooting, physical drill, marching, camping, sanitation, care of self and equipment, drills in the tactical duties of his branch of the service, *and discipline.* There is nothing in this list that cannot be much better taught in the field than in barracks, and field training is therefore ideal for the enlisted man, but an officer must know more.

The prospective officer studies the Art of War, so that, instead of blindly leading his troops as he is told, he has some intelligent idea of the purpose of it all. He studies Military History, for there is no better preparation for conducting campaigns than by the study of past operations. Napoleon was a great believer in the efficacy of study as preliminary to leadership, and is on record as having shown marked preference for a man known to be a deep student of military science over one of much experience but little military education.

The student officer must also learn the theory of his practical work. A soldier may know the mechanical processes of making a road sketch, but the officer must know the principles of surveying involved, in order to become an *instructor;* the soldier may be able to construct a satisfactory firing trench, but *some officer* must decide where that trench is to be located, and the type to be constructed, in order to best attain the desired result; a sergeant may erect a spar bridge, using timber of the correct size to carry the load safely, but is was an officer who *first computed* the sizes of timber necessary for the various spans, and put them in the

Field Manual where they became accessible to the sergeant.

In short, the officer must acquire a considerable theoretical training and, while his education is not complete without field service, neither is the latter sufficient in itself. It is told of von Moltke that he valued exceedingly an old black-board in his quarters. Upon this board he worked out problems in tactics, strategy and map maneuvers; laying out hypothetical situations, considering the conditions and location of his own forces, similar data regarding the enemy, preparing a plan of action, and writing out the necessary orders to his subordinates to carry out the plan adopted. To this training he largely attributed the great success of his campaigns in the Franco-Prussian War.

Finally, the whole question of volunteer officers reduces itself to one of expediency. If a sufficient number of fully trained officers are not available, then we must make use of the best material we have, and in such a case many graduates of the training camps would undoubtedly receive commissions. While not possessing all the qualifications that could be desired, these men would be vastly preferable to the political appointees who officered many of the volunteers in the Spanish War.

To the prospective training camp recruit, therefore, the following advice may well be given.

1. If you have an opportunity of attending this camp, do so, and go again each summer if the camps are held, for there is something you can learn at each tour of duty.

2. Do not imagine that your service *entitles* you to a commission, but work as if it were certain that you *would* command troops in our next war, and make it a point to learn *all* that you can regarding an officer's job.

3. Supplement your field training by home study.
4. If you can possibly do so, follow up your training by joining some National Guard organization.

It has been urged that National Guard officers, as a class, regard the system of Training Camps as a sort of unfair competition to their efforts at building up their own organizations, by offering more attractive service and precedence in the matter of volunteer rank, without the disadvantages and inconveniences of service in the National Guard. The following letter from the Commanding Officer, National Guard New York, to the Officer in Charge of the Military Training Camps, published in the descriptive circular of these camps, is self-explanatory:

"HEADQUARTERS N. G. N. Y.

New York, January 17, 1916.

"The question is sometimes asked whether there is any conflict of interest or of effort between the organizations of the National Guard and the training camps for college and business men. This question may not only be answered emphatically in the negative, but may be affirmatively stated with equal emphasis that the training regiments have been of benefit to the National Guard, of this State at least. A very considerable number of men of the Plattsburg training regiment have joined organizations of the New York Division, some as commissioned officers and some as enlisted men.

"Wholly aside from the foregoing there is another aspect of the training camps which should not be lost sight of. There are in some localities men who desire military training, but who are so circumstanced that they cannot make available for the purpose the amount of time demanded by service in the National Guard. Some of the men in this class find it possible to devote thirty days for training during the summer

months. The training camps furnish the needed opportunity for men in this class. These camps are therefore performing a service to the nation in respect to such men, which it is not possible for the National Guard to perform.

"I have no hesitation in urging upon officers of the National Guard throughout the State their fullest co-operation in support of the excellent movement represented by the training camps. In New York State facilities have been provided in some of the armories for detachments of men of the training camps who desire to continue the work begun at Plattsburg.

(Signed) JOHN F. O'RYAN,
Major General, N. G. N. Y."

At the beginning of this chapter there were listed five ways in which a military training might be obtained, four of which have been discussed. That remaining, the National Guard, will be treated of in the following chapter.

III.

THE NATIONAL GUARD.

The land forces of the United States as at present constituted (February, 1916) consist of:

1. The Regular Army.
2. The Organized Militia (National Guard).
3. The Volunteers.

History. The militia comprises all able-bodied male citizens between the ages of 18 and 45, and under the Constitution Congress has the authority to call forth the militia for the purpose of executing the laws, suppressing insurrection and repelling invasion, also to provide for organizing, arming and disciplining the militia and for governing such part of them as may be employed in the service of the United States, reserving to the states the appointment of officers and the authority of training the militia according to the discipline prescribed by Congress.

It was originally required that the militia be mustered once a year, after which there would be a drill by some former officer of the Army or by some officer elected or appointed from among the militiamen. The evolutions executed on these "Training Days" were fearful and wonderful to behold, and yet these were the only forces that stood between the United States and absolute annihilation, there being practically no Regular Army at this time.

The action of the militia has been most disgraceful in every war in which they have been engaged. All during the Revolution they were sent to the army in large numbers by the various states, and promptly de-

serted when harvest time came or when they tired of the service. In the War of 1812 a force of 2,500, largely militia, abandoned the National Capital to a force of 1500 British, after a loss of 8 killed and 11 wounded! Short term volunteers have invariably insisted upon leaving for home immediately upon the expiration of their term of service, regardless of the military necessities of the moment. The cause of these defections is apparent—lack of training, and it is due to these very glaring faults of the system as it then existed that the militia worked out its own remedy.

There were in those days men who had military foresight, just as there are at present, and these men, many of whom had served in the Colonial or Indian Wars, began, as a protest against the burlesque drills of the annual "Training Days," the drilling of independent companies and troops of men from their own neighborhoods. These organizations, which had no connection with the War Department, were maintained at their own expense, and were soon able to completely outshine the militia in their annual drills. Some of the smaller units were eventually combined into battalions and regiments, uniforms were adopted, and the *National Guard,* as they called themselves, became the beginning of a disciplined force.

The War Department, recognizing the increased efficiency of these troops over the raw militia, eventually admitted them into the scheme of the nation's land defenses, though at first with little supervision and practically no support. The states, also, encouraged the movement as tending toward a better training of their militia, and early acquired supervision over the National Guard. There was no authority for Federal control except as a portion of the militia, so the term *Organized Militia* was applied to those forces which were organized and under arms, to distinguished them from the great mass of the *Unorganized Militia.*

Even then, however, the National Guard was not highly esteemed as a national force. Its functions were largely social; and its tours of field service were characterized by much pomp and display. Effective use of the rifle in executing the Manual of Arms took precedence over its use as a fire-arm, and the drill was largely confined to close-order infantry formations. In the scheme of defense it was contemplated to call out the Organized Militia only *after* the Volunteers had been recruited and mustered into service. In fact, it was looked upon as a home guard, not intended for active service.

The Spanish-American War gave the National Guard its real awakening. Many organizations which desired to volunteer bodily found that they could not be mustered intact into the service of the United States, but must volunteer individually. There was no machinery for taking over the various regiments and companies as organizations, so that practically the same confusion resulted as in the enlistment of volunteers, each man being required to enlist individually. In the field it was found that armory drills had not fitted the men for the hardships of tropical campaigns, nor to combat successfully the camp diseases which attacked the mobilized troops.

The National Guard of To-day. With the end of the war and the reorganization of the Army, came a call for increased efficiency in the National Guard. By means of the so-called Dick bill (1903), the Organized Militia became a portion of the first line of defense, to serve with the Regular Army and to be called out in advance of the Volunteers. Advancement has since been rapid. All organizations are now inspected regularly and judged by their field efficiency alone. Joint maneuvers with regular troops have simulated war conditions. Officers of the militia have been admitted to the Service Schools of the Army, and have later ren-

dered valuable service as instructors in their own commands. Army Officers of the various arms of the service have been appointed Inspector-Instructors to corresponding troops of the militia, resulting in great profit to the latter and in greatly increased fellow feeling and understanding between the two services.

The Organized Militia of to-day is a far cry from the "Hay-foot, Straw-foot," drills of the early 19th century.

Defects of the National Guard. But much as the National Guard has advanced, there are yet great strides to be made before it can justify itself as a first-line defensive force. There are excellent organizations in the Guard, and there is much individual excellence, but as a whole it leaves much to be desired.

Inefficiency, as applied to an organization, must be considered as a relative term. National Guard troops are not as efficient as those of the Army; various organizations of the former are less efficient than others; while any one of these units is vastly more efficient than the militia of Colonial times. To dub a regiment or company "inefficient," therefore, does not necessarily mean that it is utterly worthless, and incapable of improvement.

In any war that we might have, with even a small state, the Army and Organized Militia combined would be insufficient, and we should have to call out numbers of volunteers from the Unorganized Militia. These men, if rushed to the front without adequate preparation, would be about on a par with the militia of Washington's time, with this exception: *Washington's militia knew how to shoot and to live out of doors.*

The first serious defect in the militia therefore, lies in its size. The training, however thorough, cannot suffice if we must in the end depend upon troops who have had *no training.* The theory of militia service is excellent. The men are not taken away from productive

pursuits for two years at a time, as in case of compulsory service in the army, and the expense is much lighter than where the Government must pay for the full time of a man, in addition to housing, clothing and subsisting him. A much larger force can be maintained, therefore, than would be possible in a standing army. At the same time, the Government must expect to receive less in the way of efficiency than from troops who devote their whole time to military matters. If the Federal Government is willing to stand the increased cost, the Organized Militia can be expanded to the size necessary to properly reinforce the Army. It has been estimated by the General Staff that ten militiamen can be maintained at the same cost as one soldier, so that an increase in the militia of 500,000 men would cost no more than 50,000 additional soldiers. Half a million *partially trained* soldiers would probably be more effective at the outset of war than a *highly efficient* force of 50,000 regulars, who would be cut to pieces in the first battle.

The second important defect lies not in the Guard itself but is nevertheless a real handicap—the attitude of the public. The old farce of the annual "Training Day" has left its imprint on the public mind, and the Guard is still regarded as an aggregation of military enthusiasts, serving simply to gratify their love of playing soldier. Even the intelligent but busy citizen is apt to look upon the service as a form of recreation which *may* become exceedingly annoying by making inconvenient demands upon his time.

A third handicap lies in the attitude of the War Department itself, and until this is altered there is little hope of changing public opinion. The distrust of the War Department also dates back to the days of the Revolutionary militia and its oft proven worthlessness in battle. The impression persists that un-

der similar conditions the present National Guard would be of as little use as then. Nevertheless, our volunteer soldiers have usually acquitted themselves with credit in battle, and the National Guard is composed entirely of volunteer material; in fact, must be regarded as volunteers who have assumed the burden of national defense before an actual call for their services in order to be more nearly ready when that call comes.

To remove this distrust, and to give to the National Guard a serious and well understood rôle, would, in the opinion of the writer, do much towards filling its ranks. If it were realized by the average man that his work in the militia would not be wasted but would count towards national defense, and that the War Department depended upon the National Guard and considered it an integral part of the land forces of the United States, then many of the objections to membership would be removed. The basic principle of the National Guard is *voluntary service* and this the average man is willing to give, even at some inconvenience and expense to himself, if he knows that he will be taken seriously and his work appreciated.

The National Defense Act of 1916. In order to afford more complete Federal control, to enforce a stricter property accountability and better attendance at drills, and to reimburse officers and men somewhat for their service and incident expense, the National Defense Act, approved June 3, 1916, contained several important provisions affecting the National Guard.

This Act provided for an ultimate increase in the National Guard to a maximum strength (to be attained in six years) of 800 for each representative in Congress, a total of about 440,000, and authorized Federal pay for officers and men performing forty-eight drills per year. It was also provided that all

officers and men should take a dual oath upon entry into service, making them Federal as well as State forces. This was done to overcome the drawback occasioned by the decision that under existing law the National Guard could not be called by the President for service outside the territorial limits of the United States. Finally, the President was authorized to draft the National Guard into the service of the United States. This provision would remove from State control the recruiting to war strength of such organizations as were drafted and the appointment of officers to fill the existing vacancies.

The National Guard provisions of this law have been condemned almost from the start. Army circles regard the pay provision as a waste of funds as far as any adequate return may be expected. The divided control, it is claimed, was not materially altered by the dual oath provision, and no amount of training can raise the militia to a high state of efficiency until this dual control is eliminated. The governor of any state, not in sympathy with the party in power, may carry his desire to embarrass the national administration to the point of disbanding entirely the Organized Militia of his own state in the face of impending war. Furthermore, if accepted bodily into the Federal service, the National Guard would be commanded by a number of general officers, of whom practically every state has a few, many of whom are political appointees purely, have no preliminary training, and are absolutely unfitted for the commands to which their rank would entitle them. And yet in active service these men would exercise command over many Regular Officers, with years of study and experience to their credit.

The only complete remedy is full Federalization and U. S. Control, and this, it is said, cannot be accomplished without amending the Constitution, which

reserves "to the states the appointment of officers and the authority of training the militia according to the discipline prescribed by Congress."

It is true that under the Constitution the states must exercise certain control over the militia. At any rate most of the states contribute largely to its support, almost wholly for purposes of national defense, but that the state can force upon the War Department any general officer or a system of training at variance with the approved schedule is not to be considered. The courses of instruction and drill for the Organized Militia are laid out by the War Department and followed under the direction of Army officers detailed to supervise them. Furthermore, the state may appoint as many general officers as its authorities see fit, but their appointment is no guarantee that they will command troops, even of their own state, in the Federal service. The War Department can regulate this very effectively by mustering in only such officers as are acceptable or as are considered necessary.

For example, in the first weeks following the declaration of a state of war with Germany, over two brigades of troops from one state were called out and mustered into the Federal service, with no higher officer than a regimental commander. These troops, once in the service of the United States, may be brigaded together or with troops from other states, and an officer of the Army appointed to command them. Thus National Guard officers in the Federal service may be limited to the rank of colonel or lower, without changing existing regulations. Furthermore, nominations for commissions in the National Guard must now be approved by the Militia Bureau of the War Department before the state may proceed to examine the candidate.

The possibility of any politically disgruntled gov-

ernor's disbanding the Guard of his state on the eve of war is too remote for serious discussion, nor would such a move, concerning only one state, affect appreciably the total forces of the nation, inasmuch as the state's full quota of volunteers would have to be supplied, and these would include the majority of the disbanded guardsmen.

The militia pay provision of the National Defense Act has been freely criticised by the press as having been forced upon Congress by the "National Guard Lobby." The writer cannot affirm nor deny the existence of any such lobby. Certainly to his knowledge there was no concerted effort in the Guard to organize or support it.

It is true, however, that the National Guard did not favor the substitute device which was proposed, the so-called Continental Army. Nor did this opposition arise, as has been stated, from the officers' fear of losing their commissions, for the proposed force could have absorbed all the officers of the National Guard twice over. Furthermore the bill authorizing this force contemplated drawing largely upon the Guard for officers. The real cause of the objection was the conviction that the Continental Army plan possessed no real advantages over the present system, beyond complete Federal control and longer periods of field service. We have seen that Federal control of the National Guard may be fairly effective in fact if not in name, and there is certainly enough difficulty now in getting men released by their employers for the ten to fifteen days required annually for field service to show the impracticability of a plan requiring thirty to ninety days in the field.

Furthermore, this field service was the only training contemplated. There were to be no armories or common meeting places, which would insure almost a complete lack of contact among members of an or-

ganization from one tour of field service to the next. Had a plan been offered which the National Guard honestly considered capable of better results than could be accomplished by its own system under proper support, it would have met with approval.

At that time, however, universal training, which by common consent appears to be the best solution of our military problems, was mentioned only as a desirable system, to which the people might some day become educated, but it was not thought advisable to attempt the passage of an act introducing it until such education had progressed further.

Finally we find the Militia Bill assailed as a failure by various guardsmen whose families or business suffered during their service on the Mexican Border. As a matter of fact, the bill has never had a try-out. The militia was called out under the provisions of the Dick Bill of 1903, and many of the organizations were mustered in and even transported to the Border without having taken the dual oath. The principal changes brought about by the Defense Act were militia pay and the dual oath, enabling the President to order the National Guard out of the United States. Neither of these provisions were taken advantage of during the Mexican Border Service. The militia could have been called into service, taken to the Mexican Border and kept there as long as invasion was imminent, if the Defense Act of 1916 had never been passed. The bill can therefore have no real test until the militia is settled down to peace training under the Federal pay provision.

IV.

MILITARY ORGANIZATION.

Military organization is of necessity the most centralized and complete system known. There is an unbroken chain of responsibility reaching from the commander-in-chief down to the rawest recruit. At the same time there is a continuous line of succession extending through all the grades and ranks, so that, however heavy the casualities, there is always one leader, and only one, to whom the army may look for orders.

In order to secure concerted action and immediate response to the will of the commander, soldiers, both officers and men, voluntarily subject themselves to *discipline,* which Col. Wagner, in his "Art of War," defines as follows:

"Discipline is that quality possessed by efficient soldiers, which enables each to appreciate and accept without question the powers and limitations of his own rank, which inspires each with confidence in the military steadfastness of his comrades, and renders obedience to lawful orders a second nature."

ARMY ORGANIZATION.

The Army is made up of two main divisions: the *Line* and the *Staff*. The latter is charged with most of the administrative work, the former with the actual fighting.

The Staff. The various Staff Departments are:

The *General Staff,* which prepares all plans for defense and mobilization, investigates all questions affecting the efficiency of the Army, and acts in an advisory capacity to the Secretary of War.

The *Adjutant General's Department,* which handles all orders, correspondence and records of the Army.

The *Inspector General's Department,* which inspects and reports upon all matters affecting the efficiency of the Army, the condition of property and supplies, and the expenditure of public funds.

The *Judge Advocate General's Department,* which is the legal bureau of the Army, and has charge of all records of general court martials, courts of inquiry, and military commissions.

The *Quartermaster Corps,* comprising the former *Quartermaster, Subsistence* (Commissary) and *Pay Departments.* This corps is charged with the transportation, clothing, housing, subsistence, supply and pay of the Army, and with all duties pertaining to military operations which are not specifically assigned to some other department.

The *Medical Department,* which supervises the sanitary condition of the Army, physical examinations, care of sick and wounded, and the management of military hospitals.

The *Ordnance Department,* which supplies arms, equipment and ammunition to the Army. This department designs and manufactures fighting material of all kinds, field equipment, horse equipment, etc., and maintains the arsenals where this material is made, repaired and stored.

The *Signal Corps,* which constructs, repairs and operates all military telegraph and telephone lines and cables, balloon trains, aeroplanes, etc.

The *Corps of Engineers,* which surveys and maps the terrain, plans fortifications and field works, and lays out lines of communication. Engineer officers of the Staff should be distinguished from those serving with troops, who are a part of the Line.

Staff officers hold military rank as do those of the Line, but do not exercise command unless placed upon duty under orders directing them to do so.

The Line. The Line comprises the fighting troops,

the *Infantry,* or foot soldiers; the *Cavalry,* or horse soldiers; the *Field Artillery,* which accompanies the Army in the field, the *Coast Artillery,* which operates the coast defenses, and the *Engineers,* who perform the duties outlined in Chapter VI.

The Line is composed of Officers, who exercise command by virtue of *commissions* issued by the President, (or, in the National Guard, by the Governor) and the *enlisted men.* The latter include *privates,* and *Non-Commissioned Officers* (Sergeants and Corporals), who exercise limited authority by virtue of *warrants* issued by their Commanding Officers.

The *Non-Commissioned Staff* of a Post, Regiment or Battalion consists of the *Sergeant-Major* and the *Quartermaster Sergeant.* The Sergeant-Major's duties correspond to those of a *first sergeant.*

TACTICAL ORGANIZATION.

A *squad* comprises seven privates and a *corporal.*

Three or four squads form a *platoon,* commanded by a *sergeant* or a *lieutenant.*

Four platoons form the *company,* which is commanded by a *captain* and is the smallest administrative unit of the army.

Four companies form a *battalion,* which is commanded by a *major,* and is the smallest unit which will operate independently in the field. The staff of the major comprises an *adjutant* and a *supply officer* (quartermaster).

Three battalions from a *regiment,* commanded by a *colonel.* A *lieutenant-colonel* may command any fraction of a regiment greater than a battalion. A regiment of engineers, under the Defense Act of 1916, consists of two battalions of three companies each, with a total strength of 1,098 officers and men.

Three regiments form a *brigade,* commanded by a *brigadier-general.*

An *infantry division,* commanded by a *major-general,* is a complete army in itself, and comprises three brigades (nine regiments) of infantry, one regiment of cavalry, one brigade (three regiments) of field artillery, one field battalion of signal troops (one wire company and one radio company), one aero squadron, one regiment of engineers, sanitary troops and wagon trains. The strength of an infantry division as now constituted (July, 1917) is 28,334 officers and men, 9,300 animals, 75 guns, 493 wagons, 627 motor trucks, and 92 machine guns, and it occupies 19 miles of road on the march. The trains comprise *field trains,* carrying camp baggage and rations, a *supply train,* an *ammunition train,* a *sanitary train* (ambulances, etc.), and an *engineer train.*

The Engineer Train contains ten wagons, one for each regiment of Infantry and Cavalry in the Division. Each wagon contains the following equipment:

Items.	Number.	Weight, Pounds.
Axes	26	130
Crowbars	7	84
Nails, pounds	—	100
Pick Mattocks	150	676
Sand Bags	450	256
Saws, hand	13	21
Saws, two-man	13	52
Shovels	300	1,200
Wire, pounds	—	25
Carborundum Grinding Wheel,	1	37
Saw Set for hand saws	1	
Saw Tool for two-man saws	1	
Saw Files with container	6	
Container for nails and edge tools	—	30
Explosives and other requisites, pounds	—	164
Total,		2,775

A *cavalry division* differs from that of the infantry by having horse artillery, mounted engineers, and cavalry regiments instead of infantry. Its strength is 10,969 officers and men, 12,133 animals, 24 guns, 453 wagons, and 24 machine guns. It occupies 11 miles of road on the march, and has the advantage over the infantry of greatly increased mobility.

An *army corps* is the proper command of a *lieutenant-general,* which grade is not at present authorized in the U. S. Army. It comprises two or more infantry divisions, one or more cavalry divisions, and additional troops, namely, a brigade of heavy artillery, a regiment of mountain artillery (depending upon the nature of the country), additional engineer troops, and aero squadrons of signal troops. There are also required additional transportation, officers, enlisted men and civilian clerks.

The mobilization, equipment, transportation and supply of such a force is a task that calls for organizing ability of the highest order. Each commander holds his subordinates responsible, not only for the actions of their commands, but for their proper instruction, discipline and all that pertains to their efficiency. He, in turn, is responsible to his superiors for the state of his own command. Duties devolving upon an officer may be assigned by him to subordinates, but his responsibility for the proper performance of this duty does not cease. Responsibility cannot be transferred.

Upon the company commander probably falls the greatest burden, as he comes into direct contact with the men, and is subject to all the annoyances of keeping them in order and in a state of efficiency. He is charged with the preparation of the raw material, as well as its effective use in the field.

The lieutenants are his main reliance in carrying on the work of instruction. They drill the company,

hold schools for the men and non-commissioned officers, inspect equipment and quarters, take the company at routine formations, and try in every way to assist the captain and leave him free for the administrative work. Every lieutenant should be capable of commanding the company, not only as a precaution against the absence of the captain, but in way of preparedness for war, when our forces will be greatly expanded, and many officers of existing organizations will be detailed to higher commands.

The major is relieved of many of the details and routine work that annoy a company commander, but he has additional responsibilities which probably outweigh the advantages of his position. His is the smallest command which will operate independently in the field, and questions of supply, field orders and the administration of his battalion will more than occupy his mind.

And so on as one goes higher. At each step the commander is freed from some of the detail, but his responsibilities are commensurately increased.

V.

MILITARY ADMINISTRATION.

Administration is army government. It is, however, usually considered as separate from the actual work of disciplining and training an organization. The term administration, therefore, may be said to include the items of money accountability, property accountability, supply, company books and records and correspondence. This classification, while not complete, will facilitate explanation of the duties of a company commander.

Money Accountability. A company officer of volunteer engineers is not likely to become a disbursing officer, nor to be charged with the custody of public funds. However, a few rules as to the handling of financial accounts of a minor character will not be amiss.

A safe rule is that no property is to be purchased nor funds expended without the sanction of higher authority, usually the Adjutant General of the Department, to whom application must be made through military channels. A citation of this authority must accompany the voucher when presented for payment.

Except in case of emergency, or to provide food for his men when traveling under orders, an officer should not make cash purchases of supplies or material, expecting reimbursement later. The person from whom such material was purchased must submit a voucher (a creditor's claim for payment), in duplicate, upon the face of which the purchasing officer certifies that the articles were received or services rendered as specified. The voucher is then forwarded to the disbursing officer for payment. The voucher must bear the following certificate signed by the creditor:

"I certify that the above account is correct and just, and that payment therefor has not been received."

JOHN DOE.

Only the original and not the duplicate is thus certified. An officer should provide himself with the proper blank voucher forms for use in such transactions.

When expenses are incurred in traveling or in an emergency, a voucher must be submitted for the proper mileage in case of travel, or for the items of expenditure in case of reimbursement. Receipts for all items must accompany vouchers for reimbursement and travel orders must be attached to mileage vouchers. The officer must certify, as payee, that the travel was performed as per the attached order and was necessary in the military service.

An officer assigned to any duty which may involve financial accountability must familiarize himself with the Army Regulations as pertaining to disbursements.

Property Accountability. All public property is of two classes: expendable and non-expendable.

Expendable supplies are those which are consumed, as fuel, forage and rations; those which are used in works, as spikes, wire, bolts and sand bags; and those which are frequently broken or worn out in use, as tent pins and axe handles.

Non-expendable property consists of tentage, arms, equipment, tools, etc. Such articles, when worn out, cannot be thrown away, but must be submitted for the action of an inspector appointed for this purpose. If found unserviceable the property is condemned by him and destroyed in his presence, and the *accountable officer* is relieved of accountability therefor, upon the inspector's certificate, approved by higher authority.

When property is lost or damaged through other than fair wear and tear in the service, the accountable officer *at once* makes application to higher authority

for a *Board of Survey,* which may consist of one or more disinterested officers. This Board investigates the causes of loss or damage, examines witnesses, and endeavors to fix the responsibility. Upon its recommendation, approved by higher authority, the accountable officer may be relieved, or held for the value of the property, in which latter case the *responsible officer* must reimburse the Government for the amount of the loss or damage as fixed by the Board of Survey. An accountable officer not satisfied with the findings of a Board of Survey may appeal to the Department Commander, whose action is final.

All property is obtained by *issue* upon *requisition.* A requisition is a statement of property required and the use to which it will be put. It must be submitted on the prescribed forms and must bear a certificate to the effect that the property is necessary in the military service. The issuing officer, at the arsenal or depot, invoices the property to the organization supply officer, who must receipt for it and account for each item upon periodical *returns,* which are complete statements of the property on hand at the date of the previous return, that received during the period, that disposed of during the period, and the amount on hand. An accountable officer may, upon *memorandum receipt,* issue property to another officer, who thus becomes *responsible* for the property so issued. He renders no returns, but must produce the property upon demand. An accountable officer, therefore, is also the responsible officer only when the property is actually in his possession.

Accountability for expendable supplies is terminated by the receipt of the officer to whom they are issued for use, or in some cases, by certificate of expenditure.

Property pertaining to one bureau must be accounted for on the return to the chief of that bureau. For

instance, property issued by the Engineer Department must not be taken up on Quartermaster or Ordnance returns.

In general orders of the War Department, accessible at every army post, are published lists of property which constitute the authorized equipment of each organization. A booklet published by the War Department, entitled "Engineer Unit Accountability Equipment Manual," contains complete information as to Engineer equipment.

Supply. The question of supply, as it pertains to the company in the field, is merely a matter of drawing forage, clothing and rations from the nearest quartermaster. It is a well-known fact that many volunteers at the Spanish War mobilization camps went hungry simply because their commanders did not know how to draw rations.

Form I illustrates the ration return used by the U. S. Army. Orders are usually issued from headquarters as to the period for which rations are to be drawn. The first return submitted, therefore, shows the strength of the command and the number of days, which include the limiting dates. Thus Sept. 1-5 indicates a five-day period. For a company of 164 men, therefore, $5 \times 164 = 820$ rations are required.

Q. M. C. FORM NO. 261
Authorized March 6, 1908.

No. ____________
[QUARTERMASTER'S NUMBER]

Ration Return of Co. H, 2nd Engrs, U.S.V.
At Camp Columbia N.Y., from June 6, 1917, to June 10, 1917.
No. of days 5, persons present 165, No. of rations 825.
Additions 6, deductions 20, net corrections −14

NUMBER RATIONS REQUIRED	GARRISON.	FIELD.	HAVERSACK.	TRAVEL.	FILIPINO.	
	—	✓	—	—	—	TOTAL 811

No. emergency rations required ——

Other issues required, quantities actually required within regulation allowance: (No. of animals 44)

SOAP.	CANDLES, ISSUE.	CANDLES, LANTERN.	MATCHES.	TOILET PAPER.	SALT, ROCK.	VINEGAR FOR ANIMALS	FLOUR FOR PASTE.	TOWELS, HUCK.	ICE
LBS.	LBS.	LBS.	BOXES.	PKGS.	LBS.	GALS.	LBS.	NO.	LBS.

(OVER)

FORM I. RATION RETURN—FACE

THIS CERTIFICATE AND APPROVAL COVER THE ISSUES INDICATED ON THE REVERSE SIDE HEREOF.

I Certify that this Ration Return is correct and that the last regular issue of rations was made by Lt-Col Richard C. Blank, Quartermaster at Camp Columbia N.Y., to include date of June 5, 1917, that the emergency rations entered (if any) are required for the enlisted men of my command, and the money value of all previously drawn and improperly opened or lost has been charged against the persons responsible; that the civil employees for whom rations are required (if any) are entitled thereto under the regulations, and that the articles, other than rations, above requested are necessary for the public service.

John J. Jones
~~In charge of~~ / *Commanding* Co. H, 2nd Engineers, U.S.V.

Approved and ordered issued. The total rations required agree with the morning reports, and the quantities of other articles ordered issued are necessary in the public service and within the regulation allowance.

____
______________________ *Commanding.*

This form may be used for a Brigade, Regiment, Battalion, Company, Troop, or Battery, a Detachment, Civil Employees, etc. Not to be signed in duplicate.

FORM I. RATION RETURN—BACK

Let us suppose that on Sept. 2d, after rations have been drawn for the five days, five men report sick and are sent to the hospital. They leave after breakfast, so take *two* meals at the hospital, which thus receives credit for their rations on this date. The company has therefore drawn $5 \times 4 = 20$ rations too many for the five-day period. But on Sept. 4th, before supper, six men from a signal detachment are assigned to the company for rations. They have one meal on the 4th, for which the company receives no credit, but they are charged with a full ration on the 5th. On the 6th, rations are drawn for the period Sept. 6-10. The five men are still in the hospital, and the signalmen are still attached, so the ration strength of the company is $164 - 5 + 6 = 165$, which, multiplied by the number of days for which drawing rations, gives $165 \times 5 = 825$ rations.

	825	
Additions....	6	(Six signalmen, one day.)
	831	
Deductions...	20	(Five men in hospital, 4 days.)
	811	=Total rations required.

The quantities which may be drawn of ice, candles, and other supplies shown at the bottom of the ration return are listed in the Subsistence Manual.

A detachment in the field, losing track of its own organization, may report to the nearest command for rations. Their own command carries a deduction or *minus,* during their absence, and the organization with which they mess carries a *plus,* or addition, during their presence. Many a volunteer has gone supperless to bed through lack of knowledge of this provision.

The clothing and equipment required by the individual soldier is listed in general orders, which also give the bureau by which these articles are issued. Each soldier upon enlisting draws a complete outfit of clothing, not to exceed in value the amount of his *initial allowance.* He also has a *running allowance* of so much per day, which is supposed to provide for renewals. Clothing required in excess of these allowances may be drawn by the soldier, but the excess cost is stopped out of his pay when his accounts are balanced at stated periods. Any unexpended clothing allowance may be drawn in cash upon his discharge from the service.

The captain is responsible for the proper outfitting of his command, and he is specifically charged with personal supervision over the fit of his men's shoes.

Clothing drawn by a soldier is marked by his name, and becomes his personal property, but it cannot be sold. Severe penalties are visited upon both seller and buyer in such a transaction, even when the latter is a civilian.

Company Books and Records. The principal report rendered by a company commander is one showing the state of the command and the status of each man. This is known as the *Morning Report,* and must be submitted daily. It consists of two blank pages, on the first of which is entered under each date the number of officers and men of each grade present for duty, present

on extra duty, special duty, sick in quarters, and in arrest or confinement. There is also entered the total number absent, and the aggregate strength of the command. Any man drawing rations with the company is carried as present, otherwise as absent. Thus men absent without leave, with leave (on pass or furlough) on detached service, sick in hospital, or in confinement where prisoners are not rationed with their commands, are carried as absent.

On opposite page are entered the *changes only*. Thus on the 18th (Form II below), Private Sweeney is still absent without leave and Corporal Kelly is still absent

MORNING REPORTS

OF

Company H, 2nd Engineers, U.S.V.
(Organization.)

FOR THE MONTH OF

September, 1917

FORM II. MORNING REPORTS—COVER

Day of the month	STATION.	C. O.—Commissioned Officers. E. M.—Enlisted Men.	PRESENT. For Duty. Captains	First Lieutenants	Second Lieutenants	First Sergeants	Q. M. and Stable Sergeants	Sergeants.*	Corporals and Lance Corporals	Cooks	Mechanics.*	Musicians and Trumpeters	Privates.*	Recruits	On extra duty	On special duty	Sick	In arrest or confinement	Absent	Present and absent	Aggregate	SIGNATURE OF COMMANDING OFFICER.
16	Camp Columbia N.Y.	C. O.	1	2	1															4		John A. Jones
		E. M.				1	1	12	18	2		2	128							164	168	
17	Camp Columbia N.Y.	C. O.	1	2	1															4		John A. Jones
		E. M.				1	1	12	17	2		2	127						2	164	168	
18	Camp Columbia N.Y.	C. O.	1	2	1															4		John A. Jones
		E. M.				1	1	12	17	2		2	127						2	164	168	
19	Camp Columbia N.Y.	C. O.	1	2	1															4		John A. Jones
		E. M.				1	1	11	17	2		2	126					1	8	164	168	
20	Camp Columbia N.Y.	C. O.	1	2	1															4		John A. Jones
		E. M.				1	1	10	17	2		2	122	1	·			3	5	164	168	

* Chief mechanics, mechanics, farriers and blacksmiths, wagoners, saddlers, and artificers will be reported under the heading "Mechanics." Sergeants, first class, will be reported under the heading "Sergeants;" privates, first and second class, under the heading "Privates."

(10)

6—1449

FORM II. MORNING REPORTS—LEFT-HAND PAGE

Day of month.	REMARKS.	
16	No remarks	
17	1st Cl. Pvt Sweeney D to A.W.L. Corpl Kelly D to A.W.L.	-8
18	No changes	
19	2nd Cl Pvts Casey, Mosely and Schmidt D to A.W.L. 1st Cl. Pvt Murphy D to sick in hosp. Serg't Myers, 1st Cl Pvts Jones and Hughes D to D.S. in Field Pvt Lane D to conf. 1st Cl. Pvt Sweeney A.W.L. to D.	+2 -14
20	Serg't Fuller lost by hon disch. 2nd Cl Pvts Casey, Mosely and Schmidt A.W.L. to conf. 2nd Cl. Pvt Lane conf. to D. Recruit Hendricks assigned from recruit depot	+4 -1

(11) 3—1669

Total +6 -23

FORM II. MORNING REPORTS—RIGHT-HAND PAGE

with leave, so there is no change in the status of the company, and no remarks are necessary. Rations are here supposed to have been drawn for five days, September 16-20, for the full enlisted strength of the command, 164 (officers not rationed). Hence two men are absent for four days and $2 \times 4 = 8$ rations must be deducted from the next ration return.

On the 19th, seven men go absent, as indicated, three without leave, one to the hospital, and three upon detached service in the field. One man is placed in confinement, but rationed with the company. The deductions for the two days, September 19-20, are therefore $2 \times 7 = 14$ rations. Private Sweeney returns from absence without leave to duty, and for the two days there is an addition of two rations.

On the 20th, one man is discharged. Deduction, one ration. Three men return from absence without leave and one enlists. Additions, 4 rations. Total deductions, 23; total additions, 6. Strength at beginning of next period, September 21-25, 160 (4 officers not rationed and 4 men absent. Rations required for next period $(5 \times 160) + 6 - 23 = 783$.

In the back of the Morning Report is space for a chronological record of general events.

Unless the morning report and ration return of a company are correctly kept and check one another, the men are likely to fare badly.

Each morning, at "First Sergeant's Call," the first sergeant proceeds to next superior headquarters and turns in his morning report, previously signed by the company commander. Ration returns, on the days when due, are also turned in to these headquarters to be approved and forwarded to the supply officer.

The sergeant-major of the battalion or regiment prepares from the company reports a Consolidated Morning Report, showing the state of the entire command.

At "Issue Call," the company quartermaster sergeant, accompanied by enough help to carry back the rations, proceeds to the storehouse and receives the rations for his company, receipting therefor to the post or regimental quartermaster sergeant. Rations will probably be issued for only one or two days of the period for which a return was submitted, as there are better facilities at the store-house for keeping provisions.

In garrison or permanent camp, a company may *save* on their ration allowance, drawing the unexpended balance in cash, which thus forms the basis of the *company fund.* This fund is also augmented by dividends from the *Post Exchange,* or store, in which the company may own stock, and from the post bakery, as savings on bread materials.

The *Sick Report* is made out only when necessary. At "Sick Call" in the morning, the men who are ailing report, and an entry is made for each, showing the date, the man's name and grade, the time of reporting sick, and whether in the captain's judgment the sickness is in *line of duty,* i. e., due to natural causes occurring in the ordinary performance of duty, or *not in line of duty,* due to the carelessness, neglect or misconduct of the soldier. The men are then sent to the surgeon, who examines them and marks after their names *duty, light*

duty, quarters, or *hospital,* as the case may demand. He also enters a remark as to whether the sickness or injury was in line of duty. His judgment in this matter supersedes and may reverse that of the captain.

The proper classification of the disability, whether or not in line of duty, is of importance as affecting any claim that may be made later for a pension.

The *Duty Roster* is a list of the men in the company liable for any particular duty, usually for guard. A separate roster must be kept for each grade, sergeants, corporals, and privates. The first sergeant is notified each day as to the number of non-commissioned officers and privates that will be required for guard the following day. The roster shows the last similar duty performed by each man, and those longest off duty are detailed.

The *Order File* is a file of all orders received or issued by the company, including General Orders of the War Department, Post, and Regiment or Battalion, and such Special Orders as affect the company or refer to its personnel.

General Orders are such as affect the entire command of the officer issuing them. For example, the following is a general order:

Headquarters 2nd Engineers, U. S. V.

Camp Columbia, N. Y., Sept. 18, 1917.

General Orders,
No. 14.

1. This command will form to-morrow, Sept. 19, 1917, at 8:00 A. M., in service uniform with field equipment, for inspection by the commanding officer.

By command of Col. Jones,
Henry C. Ross,
Capt., 2nd Engrs., U. S. V.,
Adjutant.

The following is a special order:

Headquarters 2nd Engineers, U. S. V.
Camp Columbia, N. Y., Sept. 20, 1917.

1. 1st Class Private William Roberts, Company H. 2nd Engineers, U. S. V., is detailed as headquarters clerk and will report to the adjutant for duty.

By command of Col. Jones,
Henry C. Ross,
Capt., 2nd Engrs., U. S. V.
Adjutant.

The *Company Fund Book* shows all receipts into and expenditures from the company fund.

The *Company Small Arms Practice Record* is a loose-leaf book or a card file containing the record practice and qualifications for each soldier in small arms firing.

The *Descriptive List* is a small pamphlet of twelve pages, of the size of a folded letter, and containing blank spaces for his complete description, military record, including previous service, service as non-commissioned officer, markmanship, horsemanship, battles, wounds, convictions by court-martial, etc., and for his accounts, including deposits with the paymaster, clothing drawn, and a record of final settlements at discharge. When a soldier is transferred to another organization or post, even if temporarily, his descriptive list accompanies him.

The *Correspondence Book* and *Document File* will be considered under the head of

Correspondence. The specimen letter (Form III, below) shows the correct form for a military communication. On the upper fold of the letter is written the place and the date, and the words

COMPANY "D"
CORPS OF ENGINEERS, N. G. N. Y
186TH ST AND FORT WASHINGTON AVE

NEW YORK CITY Sept. 11, 1916.

FROM - Commanding Officer, Co. D, 22nd Corps of Engineers, N. G. N. Y.

TO:- Commanding Officer, 22nd Corps of Engineers, N. G. N. Y.

SUBJECT:- Mustering Private Henry, Co. D, with Co. J.

1. Permission is requested to muster Private John C. Henry, of this company, with Company J, 22nd C. of E., on Sept. 25, 1916.

2. Private Henry was absent on the night of Sept. 4, 1916, and could not be mustered with this organization.

John Doe

Captain, Corps of Engineers, N. G. N. Y.

1st Ind.

Hdqrs 22nd C. of E., Sept. 15, 1916 - to C. O., Co D.

1. Returned by direction of Col. Smith.
2. Information is requested as to the reason for Private Henry's absence from the muster of his company on Sept. 4, 1916.

Richard Roe

Capt. Corps of Engrs, N. G. N. Y.,
Adjutant.

2nd Ind.

Co D, 22nd C of E., Sept. 18, 1916 - to C. O., 22nd C. of E.

1 Returned.
2. Private Henry's absence on Sept. 4, 1916 was due to an injury to his foot, caused by his dropping a heavy casting upon it in the shop where he is employed.
3. Private Henry was, from Sept. 1 - 10, 1916, under the care of a physician, whose certificate is inclosed.

J D

(1 Incl.) Capt., C. of E., Cmdg. Co. D.

3rd Ind.

Hdqrs 22nd C. of E., Sept. 18, 1916 - to C. O., Co. D.
1. Approved.
2. The return of this paper is requested. By direction of Col. Smith.

R R

Capt., C. of E., Adjt.

(Second Sheet)

4th Ind.

Co. D, 22nd C. of E., Sept. 20, 1916 - to C. O., 22nd C. of E.

1. Returned.
2. Noted.

J D

Capt. C. of E., Cmdg. Co. D

(Rubber Stamp)
Rec'd back Hdqrs 22nd C of E 9-20-1916.

FORM III. MILITARY COMMUNICATION

"*From,*" "*To,*" and "*Subject.*" In filling out a heading, designations of officers rather than their names, should be used, thus: *From:* Commanding Officer, Co. H, 2nd Engineers, U. S. V.

If a letter is to go higher than the next superior headquarters, it is addressed to the officer who will take action, adding under his name "(Through Military Channels)" and sent to the next superior headquarters to be forwarded.

The subject should not contain more than ten words, and no letter must refer to more than one subject.

The heading as indicated, and *nothing else,* must occupy the top fold.

The body of the letter follows, without salutation, the paragraphs numbered, and a margin of one inch at the left. If written upon a typewriter, paragraphs are single spaced, and separated by a double space. The signature follows the body of the letter *without closing expressions,* such as "Yours respectfully." If the grade and position of an officer are given in the heading, they are not repeated in the signature.

Indorsements follow the signature in order, numbered consecutively. They must indicate the organization by whom sent, the headquarters or officer addressed, and, if transmitting indorsements only, may simply contain the word "Forwarded" in their body.

It is customary in replying to a letter to return the original by indorsement, instead of writing a second letter. If inclosures are sent, their number is indicated at the left of the letter, opposite the signature.

Two carbon copies of a letter are made, one of which is retained by the sending officer, the other, signed by initials only, or by a typewritten signature, is forwarded with the letter. This is for the files of the receiving officer if the letter is returned by indorsement or forwarded to a higher headquarters. Press copies are no longer used.

In mailing, the top fold is folded *back,* and the bottom fold *up,* covering the body of the letter. The top fold, with the heading, is therefore left on the outside of the folded letter, taking the place of the former briefing.

In the *Correspondence Book* is kept a record of the writer of each letter sent or received, the person or office addressed, the date forwarded, a brief of the contents, and a record of the action taken. The form letter shown would have the following entry:

53
C. O. Co. D, 22nd C. of E., N. G. N. Y.
to C. O. 22nd C. of E., 9-11-16.
Requests permission to muster Pvt.
Henry with Company J, 9-25-16.
Rec'd back 9-18-16.
To C. O. 22nd C. of E., 9-18-16.
Rec'd back 9-21-16, Approved.
Noted and returned.

This would be cross-indexed under the headings *muster* and *Henry.* A copy of the letter is numbered serially to correspond with number of the entry in the Correspondence Book, the indorsements relating to the action taken are copied upon it, and the copy is filed in the *Document File.*

VI.

ENGINEER TROOPS IN THE FIELD.

DUTIES.

According to the Official Bulletin of the General Staff, U. S. Army, Vol. I, No. 4, December, 1914, the duty of engineer troops in the field is to apply engineering science to the emergencies of modern warfare in order to protect and assist troops, to ameliorate the conditions under which they are serving, to facilitate locomotion and communication, and whenever the occasion requires to act as purely combatant troops.

Captain Thomas M. Robins, Corps of Engineers, U. S. Army, in his lecture to the United Engineering Societies upon "Organization and Duties of Engineers in War" used the following apt comparison: "An army in the field is a machine which may be worn out and rendered unserviceable by interior as well as exterior friction. It is the duty of the engineer to lubricate this machine and at the same time to throw sledge hammers into the gears and cogs of the enemy's machine, to prevent its working as he wishes."

In the performance of these duties engineers are trained and equipped to supplement or amplify by scientific measures the efforts of combatant troops in the services enumerated below and such other special services of an engineering nature as may arise and are beyond the technical training of combatant troops, or such as require the use of engineering implements and material not supplied to combatant troops.

Scope of Services.

(a) The service of reconnaissance, including tactical reconnaissance, engineering reconnaissance, surveying, mapping, and sketching, panoramic sketching, photography, drafting, and map reproduction.

(b) The service of castramentation, including the selection, laying out and preparation of camps, the reconnaissance and municipal and sanitary engineering incident thereto, and the installation, operation and maintenance of water-supply systems.

(c) The service of fortifications, pertaining both to the attack and the defense and including the selection of defensive positions when out of the presence of the enemy; rectification of and assistance in the selection of such positions in the presence of the enemy; the location, design and construction of the more important field works; assistance in and supervision of the construction of hasty defenses wherever possible; the supply of tools and materials; and the reconnaissance, demolitions, water-supply and communications incident thereto.

(d) The service of sieges, pertaining both to the attack and defense and including the selection and location of defensive lines, lines of investment and siege works, the construction of saps, mines and countermines; the operation of search-lights; preparation for and assistance in attacks, counter attacks and sorties; organization of captured points; and the supply of tools and materials.

(e) The service of demolitions, including the carrying out of all work of this nature authorized by the commander and not within the scope of other troops.

(f) The service of battlefield illumination, including the supply and operation of search-lights and other means of battlefield illumination.

(g) The service of general construction, including the location, design and construction of wharves, piers, landings, storehouses, hospitals and other structures of general utility in the theater of operations.

(h) The service of communications, including the construction, maintenance and repair of roads, ferries, bridges and incidental structures; the selection and

preparation of fords; the construction, maintenance and operation of railways under military control, and the construction and operation of armored trains.

(i) Special services, including all municipal, sanitary and other public work of an engineering nature which may be required in territory under military control.

The services in the above list are executed under the supervision of engineer officers by engineer troops, by details from other troops, by civilian labor or by any combination of these means as the particular circumstances may require.

Time is usually all important and labor is plentiful, and wherever the labor of other troops can be profitably used such troops should be provided promptly and used freely, the tools of the engineer train being brought up for this purpose.

ORGANIZATION.

The engineer troops and equipment of a division consist of a regiment of engineers (two battalions of three companies each), and an engineer train with supply section, searchlight section and ponton section. The war strength of a regiment of engineers is 1,098 officers and men and 453 animals, exclusive of the engineer train. (See Appendix III.)

An infantry division numbers about 28,000 so that the engineers form about four per cent of the combatant troops, which is somewhat less than the proportion considered necessary in foreign practice. This proportion may be increased by assigning additional engineers to the field army.

An engineer company (foot) consists of four officers, mounted, and 164 enlisted men, of whom 36 are mounted, as follows:

1	captain,	mounted
2	first lieutenants,	mounted
1	second lieutenant,	mounted
1	first sergeant,	
3	sergeants, first class,	1 mounted
1	sergeant, mess,	
1	sergeant, supply,	
1	sergeant, stable,	mounted
8	sergeants,	1 mounted
18	corporals,	4 mounted
1	horseshoer,	mounted
1	saddler,	mounted
3	cooks,	1 mounted
2	buglers,	
31	privates, first class,	8 mounted
93	privates,	18 mounted

4 wagoners (teamsters), only when company is acting alone. Otherwise all wagoners are attached to the regimental headquarters detachment.

EQUIPMENT.

The following is the combat train of each company:

Two wagons containing instruments, tools, tackle, explosives and supplies. (Mainly for the foot troops of the company.) Practically identical loads on each.

Eight pack mules, with two demolition packs, three packs of tools, tackle and supplies, and three packs of grain, rations, additional tools or explosives. (Mainly for the mounted detachment of the company.) It will be observed that each company is so organized and equipped that it can provide the following working parties:

(a) The small parties necessary for demolitions, sketching, mapping, etc.

(b) A mounted detachment, especially provided for work at a distance from the foot portion of the company.

(c) Two almost identical foot detachments of from 50 to 65 men. In addition to the equipment carried in the combat trains of the companies there is the following equipment:

(a) *Battalion combat train.*
1 wagon (blacksmith equipment).

(b) *Regimental combat train.*
1 wagon (map reproduction equipment).
1 spring tool wagon (surveying, drafting, photo and reconnaissance equipment

(c) *The Engineer Train.*

(1) Ten wagons, one for each infantry and cavalry regiment of the division, carrying reserve entrenching tools, as follows:

260	Axes.	4,500	Sand Bags.
70	Crowbars.	130	Hand Saws.
1,000	lbs. Nails.	130	Saws, two-man.
1,500	Pick Mattocks.	3,000	Shovels.
250	lbs. Wire, smooth.		Tool Sharpeners, etc.

(2) 4 wagons, ammunition for Engineer regiment.

(3) Searchlight Section, 6 power, 6 light units.

(4) Ponton Section, two divisions (450 feet) reserve (wooden) bridge equipage. Details from the Engineer regiment construct bridges with this equipage.

DETAILED DUTIES.

On the March, engineer troops verify, correct, and amplify existing maps or prepare and reproduce road sketches in the absence of other maps. They examine routes and local resources with a view to their utilization. They mark roads and furnish guides when necessary. In an advance they remove obstacles, and in a retreat they place obstacles to check the advance of the enemy. They execute demolitions, especially in a retreat, and destroy materials, stores, and natural resources whenever so ordered. They prepare roads, bridges, fords, and ferries, and strengthen structures,

make repairs, or build entirely new ways of communication and assist the artillery and heavy vehicles in difficult places. They prepare photographs to supplement reconnaissance and records.

The Advance. Regardless of the character of the march, delays are always to be expected either from the enemy and his activities or from bad roads, accidents to road structures, or from some other cause, and the troops, to make the way clear and expedite the march, ought, unless other considerations forbid, to be near the head of the column to attack the obstruction as soon as it is discovered and obviate the delay incident to bringing them and their combat train up from the rear along a road encumbered with other troops and vehicles. Therefore a working unit of engineers, preferably a company, should be at the head of the column and should form a part of the support of the advance guard.

The Retreat. In a retreat there is always the presumption of a pursuit by the enemy, and the disposition of the engineers might be about as follows for a division marching on a single road:

1 battalion, ahead of the trains.

2 companies, at the head of the leading troops.

1 company, as part of the rear guard.

This disposition is merely a suggestion and not a type formation.

The duty of the first body is to insure that the road is open and the way clear and that of the second to see that these conditions are maintained. The duty of the third, in addition to assisting in the conduct of the retreat, is to delay the advance of the pursuing force by placing obstructions along the route or routes and by actual combat when necessary. The main part of this company will be with the reserve of the rear guard and will *prepare* bridges, etc., for demolition. The mounted detachment will be with but ordinarily will

not form a part of the rear cavalry. Their function is to make the demolitions after all the troops have passed, and then by means of their mounts rejoin the rear party and repeat the operation. If the road is to be obstructed by fallen trees and other such obstacles, the main part of this company may fall farther to the rear than above indicated.

The Attack. In the attack, the engineers reconnoiter for and facilitate the advance of the other troops by repairing and constructing roads, bridges, and ferries, improving fords, and making clearings to facilitate communication and deployment. Engineer troops accompany the attacking line for the purpose of destroying and clearing away obstacles, destroying hostile mines, organizing captured positions, and for destroying guns, works, and stores which can not be held. They assist in clearing the field of fire for the artillery and in arranging for observation of fire, including the construction of high observing stations. They destroy or blockade ways of communication to guard against flank attacks. They supply tools to troops taking up a position in a deliberate attack and assist in the preparation of fortified portions of the line. They are specially concerned with the construction of supporting points to check temporary reverses, works to guard against counter attack on the flanks, and works of general interest, such as dressing stations, ways of communication, and the like. They give assistance to the artillery for the advance preparation of new positions, so that the artillery may move from one position to another with the least loss of time. They operate searchlights or other means of illumination used in night attacks; they mark roads and trails leading along the positions, and, if necessary, supply guides; they make the engineer reconnaissance to locate and procure tools and materials and otherwise utilize available local resources to the fullest extent; they will make

and reproduce such position and place sketches, photographic views and panoramic sketches of hostile lines as may be practicable. Engineer troops will be used on the firing line whenever it is desirable to bring all available rifles into action, or when their position is such that they can render the most effective service by fire action.

The combat train advances with the companies as far and as rapidly as possible, so that tools and supplies shall always be near at hand; but they should be halted off the road when they can no longer advance and should never be allowed to delay the advance of the troops.

If the attack encounter fortified positions, the engineers are used in the firing line to destroy obstacles or mines, to handle grenades, to accompany and assist the brigade commander in reconnaissance of the hostile position, and assist in organizing captured positions against counter attacks.

The strength of the enemy's fortifications will determine the rate of advance, and the slower the advance the greater will become the usefulness of the engineer troops. The operation of searchlights and other means of battlefield illumination will be employed in protracted attacks, and the illumination of roads, etc., will be required.

The Defense. On the defense the engineers assist in clearing the foreground, placing obstacles, and determining and marking ranges, and are specially concerned in the construction of works of general interest, including dummy trenches, bomb proof and splinter proof overhead covers, screens, dressing stations, observation stations, and supporting points. They assist in preparing woods, houses, and villages for defense, and in repairing damaged works. They operate searchlights and other means of illumination. They destroy or blockade ways of communication and destroy stores

and other resources or structures that may be useful to the enemy and are certain to fall into his hands. They prepare land mines, fougasses, and grenades. They distribute the tools to troops taking up positions, prepare positions fortified in advance of their occupation, and supervise civilian working parties on such lines. As in the attack, they improve or construct roads and other ways of communication, including field railways, and facilitate the movement of troops and supplies throughout the entire position. They will make such sketches and reproduce such photographic views as may be practical. They make the engineer reconnaissance to locate and procure tools and materials and other local resources.

Their numbers prohibit them from doing all the clearing or all the entrenching, even if such were otherwise desirable. They assist in laying out and constructing the trenches, obstacles, overhead cover, dummy trenches, etc., and in clearing the foreground and concealing the position.

Sieges. In sieges engineer troops have the same duties as in an attack or in a defense, according to whether they are besieged or besieging. They have also the duties required of them in camps, and are specially charged with the location and construction of siege batteries, parallels, approaches, mines and countermines and obstacles. They prepare for and assist in assaults and sorties, destroy obstacles, hostile mines and works, and prepare captured positions for defense.

Prior to assaults or night attacks the ground to be passed over should be carefully reconnoitered and mapped, if practicable, and engineer officers should act as guides to the attacking troops. The columns should be accompanied by engineer troops with the necessary tools and equipment to assist the advance and to strengthen any position captured.

In Camp (not short halts or bivouacs) the engineers lay out the camp and make the necessary surveys or sketches of the camp and outpost and reproduce maps for the command. They prepare and mark the watering places and may be called upon to install the water supply. They construct the main drainage system for permanent camps and other works of sanitation requiring special skill or equipment. They assist in the construction of shelters. When the camp is fortified the engineer troops have the same duties as in a defensive position. They carry out such demolitions as may be required. They repair roads and bridges, constructing such new ones as may be required, and prepare the terminal facilities, both by rail and water, and mark the routes of communication and deployment and construct and operate portable railways. They construct buildings of general interest and such other engineering works as may be required of them. They also do such photographic work as may be required, and make special examination of the terrain with a view to engineer work and the utilization of local resources.

A single regiment cannot do all the technical work in a camp as rapidly as its completion is desired, but by using the engineer troops for such work only and giving them such assistance in unskilled labor as may be required, the rapidity with which roads, drains, huts, buildings, etc., can be constructed is surprising. The ordinary guard, police, and fatigue work for the general camp and all other details not requiring technical skill nor equipment should be made from other troops and details from the engineer troops should be confined to such duties as make use of their special training and equipment. When practicable the engineer troops should be sent to the camp site well in advance of the other troops, except signal and quartermaster troops.

VII.

FIRE ACTION.

To comprehend the subject of field fortifications it is necessary to know and understand the effect of fire both from small arms and artillery, destructive forces quite different in action from those against which the engineer must ordinarily protect his works.

To shoot straight, to direct a projectile true to its intended mark, is a feat of engineering just as much as the true pointing of a theodolite in a geodetic survey, and one performed under vastly more difficult conditions: great personal danger, unknown range or windage, and no system of least squares that has yet been invented to "adjust" a wide shot after it is fired, even if the source and amount of error is known. It is the belief of many that proficiency in rifle shooting comes only with actual practice in firing, and that only men with keen eyesight and iron nerve can hope to become expert riflemen.

As a matter of fact, most riflemen of the writer's acquaintance have probably less than normal eyesight. Most of them wear glasses in shooting. It is not the eyesight, but the manner of using it which counts, and the modern holds with the sling will correct any tendency towards unsteadiness due to nerves.

Rifle Instruction. It is easy to comprehend that a man of intelligence, instructed as to reading a vernier, as to "bisecting" a target, and in the mechanism of the transit, tangent screws, etc., might make a very creditable reading of an angle at his first trial. Upon this fact is based the system of training in Company D, an intensive system by which we claim to make a good shot of a man *before he ever fires his rifle.*

Marksmanship embraces the following principles: knowledge of the rifle, of sight setting, sighting, and of holding the aim while pulling the trigger.

When a recruit joins Company D, an officer or non-commissioned officer gives him the following instruction in the rifle:

He is instructed in the data regarding the rifle, its name, length, weight, caliber, sight radius, etc., and in the correct nomenclature of the parts.

He is required to dismount the bolt and magazine mechanism repeatedly, and is instructed in the proper manner of caring for and cleaning the piece, to work always from the breech in cleaning, in order to avoid injury to the rifling at the muzzle and consequent loss of accuracy.

He is practiced in the manipulation of the rifle by loading drills with dummy cartridges, until in his hands it is no longer a source of danger to himself or "innocent bystanders."

The recruit is next shown how to use the sights. Enlarged patterns of the sights are cut from sheet brass, and mounted by hinges on a wooden bar. An additional hinged flap, containing a small pin hole, is mounted at the eye end of the bar. The pin hole is on the line of the center of the rear sight and the top of the front sight, so that in looking through it the rear and front sights always appear in perfect alignment.

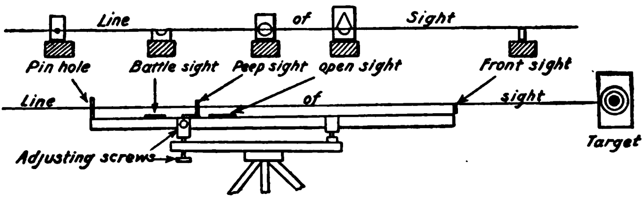


FIG. 1. BAR FOR INSTRUCTION IN THE USE OF SIGHTS

First Exercise. The instructor sets the sights, peep, open or battle-sight, on a target across the room. The

recruit, looking through the pin hole, sees the rear and front sight and the bullseye in proper alignment. The bar is then moved and he is required to reset on the target, using the adjusting screws.

Second Exercise. The pin hole flap is turned down out of the way, and the recruit is required to align the sights and bullseye, centering the front sight in the rear peep or notch as well as he can. He checks the result by turning up the rear flap and looking through the pin hole. Any error in "centering" the front sight now shows clearly. The instructor can also see the amount and direction of the error and take steps to correct it.

Third Exercise. This apparatus may also be used to illustrate the importance of fixing the eye on the target instead of on the front sight. The target is covered and the recruit directed to gaze intently at the front sight. The target is now uncovered and is seen indistinctly, as his eye is out of focus. The front and rear sights are then laid down, and his eye, looking through the pin hole, is focussed on the target. When the sights are raised, he finds that he can, still looking intently at the bullseye, see *through* and *over* the sights and tell when they are correctly aligned, *without gazing directly at them.*

The positions are then demonstrated, with explanations of the reasons for each detail, and the sling hold is illustrated and insisted upon for each man.

For instance, in the kneeling position, the weight rests on three points: the sole of the left foot, the right knee and the right toe. For steadiness, these three points must be as widely separated as possible, preferably at the vertices of an equilateral triangle, similar to a tripod. The left foot points towards the target, the heel well forward so that the leg below the knee is vertical. The right leg rests squarely across the line of fire. If the left heel is drawn back, the body

will rock backwards and forwards and the sights will move vertically on the target. If the right knee is brought close to the left heel, the right leg pointing to the rear, the body will sway from side to side, and the sights will move horizontally on the target. The left elbow, supporting the rifle, must hang over the left knee-cap. A trial at supporting the elbow on *top* of the knee will show the unsteadiness of this position.

The use of the sling is advocated as it steadies the aim, assists the "hold" while pulling the trigger, and tends to minimize the recoil.

Similar instruction is given regarding other firing positions.

He is now prepared to shoot, but in order to coordinate all that he has learned regarding the manipulation of the rifle, positions and sighting, without preliminary waste of ammunition, and to prevent developing *flinching* or *gun-shyness* from the recoil and report, there is yet another step by which he may apply all that he has learned and actually take his position, aim, hold, fire, and "call his shot," before going upon the range.

The Hollafield Rod consists of a brass tube which fits in the bore of the rifle and contains a movable plunger or needle, sharpened at the outer end. This needle, held in place by a spring, rests down upon the firing pin, which, when the trigger is pulled, drives the needle out about six inches in front of the muzzle, from which position it is immediately returned by the spring. A double target is used, the vertical distance between the bullseyes being equal to that from the tip of the front sight to the center of the bore. (Fig. 2.)

The needle will puncture the lower target at the corresponding point to that on the upper target which is covered by the sights at the instant of firing. The targets are reduced in size so as to subtend the same

visual angle at six inches in front of the muzzle as a standard target at the regulation range.

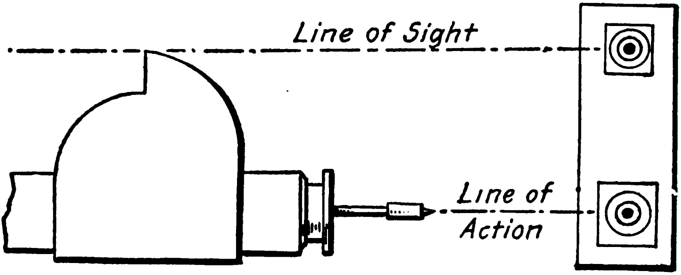


FIG. 2. THE HOLLAFIELD ROD

By using a shorter rod, and placing in the chamber of the rifle a dummy cartridge containing a movable plunger, the method of loading may be practiced. The firing pin strikes the plunger in the cartridge, which passes the blow on to the needle of the Hollafield Rod and operates it as before. These cartridges may be loaded into the rifle by clips, the same as service ammunition, and rapid or magazine fire may be simulated in all respects except as to the recoil and report.

The recruit is now ready for the range, the foregoing instruction having occupied about two or three hours, depending upon his adaptability. He is familiar with all except the recoil and the report, and on the indoor range the former is missing, owing to the reduced charges used. However, cases of flinching do occur, and are usually corrected by the instructor's loading the man's rifle for him, sometimes with an empty shell, so that he never knows in pulling the trigger whether or not the gun will go off. Flinching is caused by anticipating the report. The report itself may cause a man to jump, but it is then too late to deflect the bullet. The practice of *calling the shot,* i. e., calling

out where the shot has struck judging from the point covered by the sights at the instant of firing, will usually fix the attention and prevent shutting the eyes or flinching. Care must be taken, however, not to call the position of the sights when *beginning* the trigger pull, as this is liable to vary greatly from their position on firing.

For describing the position of hits on the target, a simple clock-face nomenclature is used. In Fig. 3, a hit at (1) is described as *a bullseye, pinwheel,* at (2), a

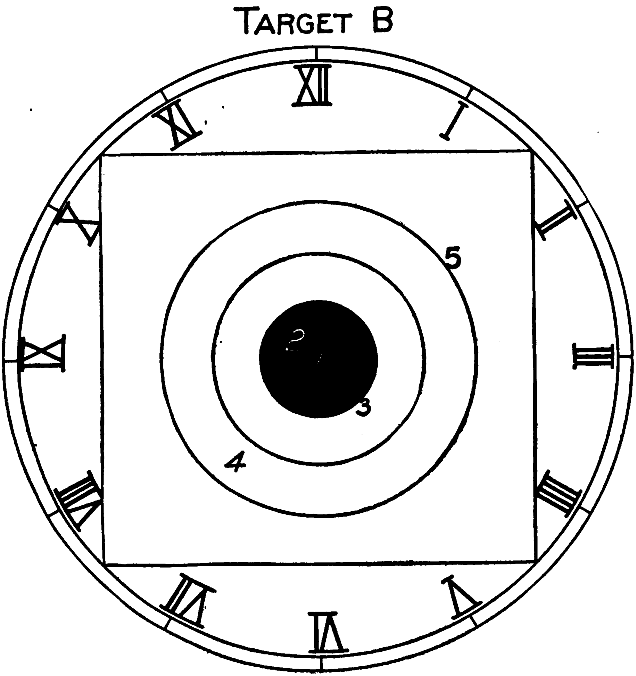


FIG. 3. TARGET NOMENCLATURE

bullseye, half in at ten o'clock, at (3), *a four, hanging on at five o'clock,* at (4) *a three half out at seven o'clock,* and at (5) *a two just out at one-thirty.*

Outdoor Firing. A similar nomenclature is adopted to describe the direction of the wind. (Fig. 4.) The clock-face is supposed to lie on the ground, the XII pointing toward the target. A head wind is a *twelve o'clock wind,* one from the right is a *three o'clock wind,* and one blowing towards the target is a *six o'clock wind.* 1, 5, 7 and 11 o'clock winds require half the correction, and 2, 4, 8 and 10 o'clock winds about the same correction, as one from 3 or 9 o'clock. A wind which changes direction continually from one

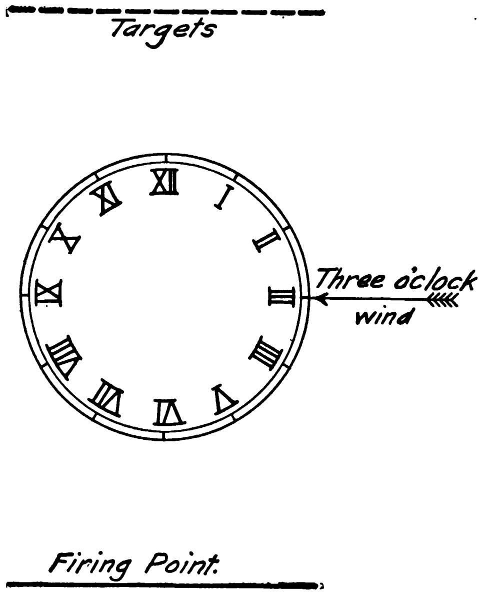


FIG. 4. WIND NOMENCLATURE

hand to another, say from 10 to 2 o'clock, as frequently happens when the targets are placed against a hill as a back-stop, is known as a *fish-tail wind.*

Outdoor firing brings into play factors hitherto unknown: wind, mirage and the varying effects of light and shade. Shooting ceases to be mechanical and becomes a matter of skill and judgment in estimating and correcting for conditions which may not be twice alike. The windage correction may vary between shots from three-quarters of a point right to the same to the left in a fish-tail wind, and the mere passing of a cloud over a target previously bright may make a difference of fifty yards in elevation at six hundred yards.

By his previous instruction and practice the recruit is supposed to have learned to aim, hold and pull correctly, and above all to have confidence in his hold, in other words to be able to *call his shot* with certainty. Unless he can do this, he cannot be sure whether a poor shot was caused by incorrect adjustment of the sights or a bad *pull.* The man who is confident that his hold should have given him a bullseye, but who gets a *three half out at five o'clock,* may change his sight setting with certainty that, conditions being the same, his next shot will strike where he aims.

Mirage, the *heat waves* that are so annoying to the surveyor, may be of great assistance to the rifleman. By focussing a telescope just short of the targets these waves may be seen running across the field like the current of a river. They give the direction of the wind, sometimes quite different from that felt at the firing point, and show sudden changes which would otherwise be unnoticed except by their effect upon the shots. From their speed, estimated in miles per hour, the *range rule,* Velocity x Range/40, gives the windage correction, to be applied against the wind, i. e., the wind gage must be moved to the right to counteract a

wind from that direction. At 600 yards, according to this rule, a 10-mile wind requires a correction of

$$\frac{10 \times 6}{40} = 1\frac{1}{2} \text{ points on the wind gage.}$$

One point on the wind gage subtends a horizontal distance of four inches on the target for each hundred yards of the range. At 600 yards a change of 1½ points varies the position of the hit by 6 x 4 x 1½ = 36 inches. Therefore a ten-mile wind at 600 yards would be sufficient to cause a shot fired without correction to miss or just strike the edge of the target (72 x 72 inches). Fig 5 shows the correction scales, both for

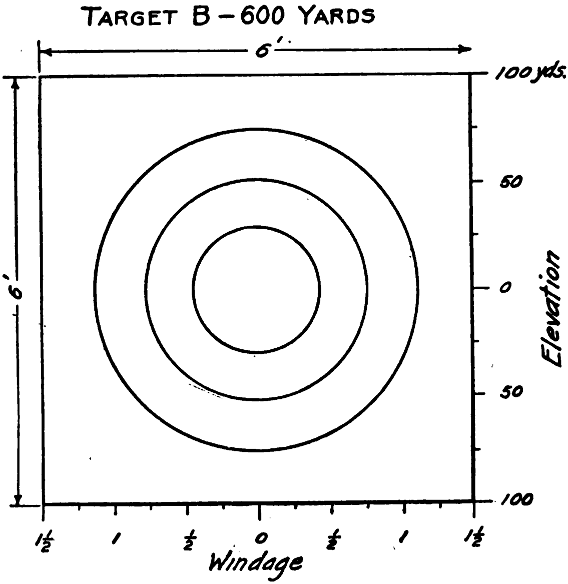


FIG. 5. CORRECTION SCALES

elevation and windage, for the B target used at 600 yards. The rule for the elevation correction is: *a change of one hundred yards in elevation will raise or lower the position of the shot by a number of inches equal to the square of the hundreds of yards in the range.* At six hundred yards, therefore, a change of 100 yards in the sight setting will change the elevation of the hit by 6 x 6 = 36 inches, half the height of the target. (Fig. 5.)

Effect of Small Arms Fire. If a number of men are firing at an object, the best shots striking it, the others missing by various margins, the whole *sheaf* of trajectories will form a cone about that of the best shot as an axis. (Fig. 6.)

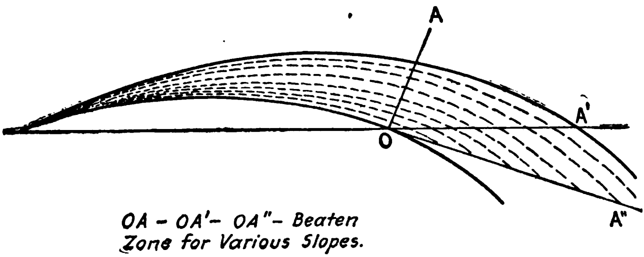


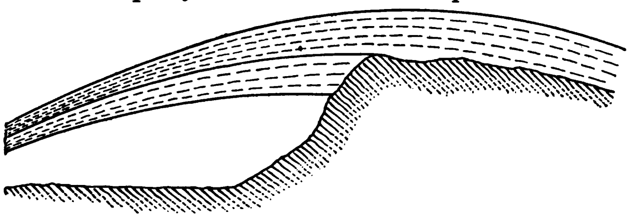
FIG. 6. CONE OF DISPERSION

This is known as the *cone of dispersion* and its intersection with the ground surface is the *beaten zone.* This cone, similarly to the stream from a fire nozzle, may be played over a field at the will of the commander by his designating the range and objective. In laying out a plan of fire action, each unit, however large or small, must be assigned its sector of fire and *kept to it.* It is natural for men to fire at what can be most clearly seen, and unless they are held strictly to a portion of the line and cover their own front thoroughly, it may happen that a section of the enemy's

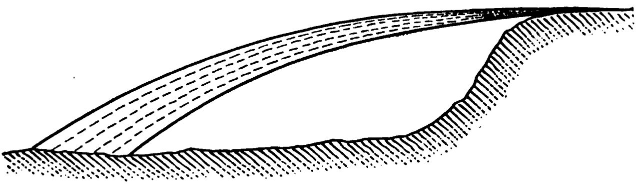
line, well concealed and not troubled by hostile fire, is able to fire with deadly accuracy and inflict heavy losses.

Rifle fire which dominates a certain space and keeps the enemy from occupying it is just as effective as that which strikes his men, and the greater the space which can be thus occupied by fire action per unit volume of fire, the more efficient is that fire.

Suppose we consider a plane surface perpendicular to the axis of the cone of dispersion. The least section of a cone is the circle, perpendicular to the axis, and therefore such a slope, facing *towards* the enemy, will be less swept by his fire than a level plain. On a re-



From Low Ground to High.



From High Ground to Low.

FIG. 7. FIRE FROM LOW GROUND TO HIGH AND VICE VERSA

verse slope *parallel* to the axis of the cone of dispersion the entire surface is swept by a *grazing* fire, and the whole slope is untenable without cover.

Fig. 8 illustrates the term *danger space.*

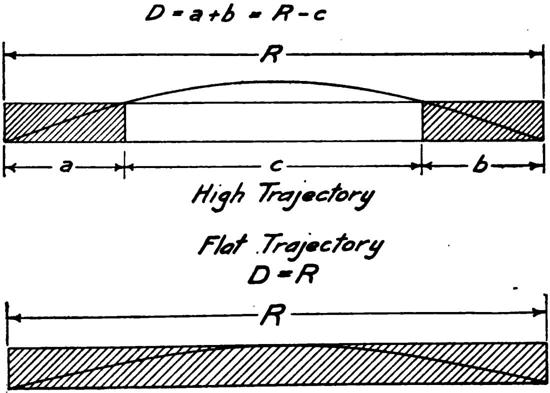


FIG. 8. DANGER SPACE

A bullet from our military rifle would be dangerous to a man standing throughout its range up to 700 yards. A slope which makes an angle with the trajectory decreases the danger space, as when firing against a hillside or from a height onto a plain, and a reverse slope, parallel to the trajectory or nearly so, permits a *grazing* fire with greatly increased danger space.

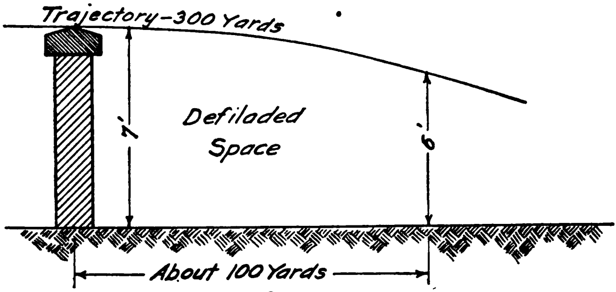


FIG. 9. DEFILADE

A *defiladed space* is one which is protected from hostile fire. A slope parallel to the trajectory increases the defiladed space formed by a given object, while a contrary slope decreases it. (Fig. 9).

PENETRATION OF RIFLE BULLET.*

Material	Maximum Penetration.	Remarks.
Steel plate, best hard.	1/16 inch	At 30 yards normal to plate, 3/16 inch req'd.
Steel plate, ordinary mild or wrought iron.	¾ inch	3/16 inch is proof at not less than 600 yards, unless the plate is set at a slope of 3 to 2, when 3/16 inch is proof at 250 yards.
Shingle	6 inches	Not larger than 1 inch ring gauge.
Coal, hard	9 inches	
Brickwork, cement mortar	9 inches	150 rounds concentrated on one spot will breach a 9-inch brick wall at 200 yards.
Brickwork, lime mortar	14 inches	
Chalk	15 inches	
Sand, confined between boards, or in sandbags	18 inches	Very high velocity bullets have less penetration in sand at short than at medium ranges.
Sand, loose	30 inches	
Hard wood—*e. g.*, oak, with grain	38 inches	
Earth, free from stones (unrammed)	40 inches	Ramming earth reduces its resisting power.
Soft wood—*e. g.*, fir, with grain	58 inches	Penetration of brickwork and timber is less at short than at medium ranges.
Clay	60 inches	Varies greatly. This is maximum for greasy clay.
Dry Turf or peat......	80 inches	

*From British Manual of Field Engineering.

Artillery fire has grown to be a most important factor in modern tactics. With the great increase in volume and accuracy which has been developed in the present war, it bids fair to almost revolutionize battle tactics and the art of fortification. The introduction of *indirect fire* and *spotting* permits a battery to take up a position of comparative safety and systematically search out the landscape.

The battery commander, with an instrument resembling an engineer's transit, places himself where the target, the guns, and some other point visible to the gunners can be seen. The guns themselves may be separated from the target by a hill or other obstacle. The observer reads the angle between the target and the *common aiming point*. A simple computation, assisted by tables, gives the gunner the angle at which his panoramic sight must be set, so that when aiming at the common point, his gun is pointed at the target. The *angle of site*, which depends upon the difference of elevation of the gun and the target, also enters into the problem, it being clear that of two points at the same distance from the gun, the higher will necessitate a greater elevation of the gun to hit it than the former. The distance from the guns to the station and to the target is triangulated or estimated.

The *spotter* is an officer located near enough to the target to observe the effect of the fire. He is connected with the battery commander by telephone and corrects the laying of the guns by reporting the results of the shots. He also picks up points which may be of importance, for instance, a section of road which must be crossed by the enemy in charging, directs the firing of a few ranging shots, until the target is struck consistently, and causes the battery commander to register the target under a serial number or letter, together with such gun data (range, azimuth, etc.) as will enable him to again find the target without further sight-

ing shots. The spotter can at any time thereafter sweep the road in question by telephoning to the battery, "Target H, shrapnel, rapid fire".

Artillery projectiles are of two kinds: *high explosive shell* and *shrapnel.* The former apparently has no limit to its destructiveness, and no structure can long withstand it. The Russians on 203-Meter Hill found that 12 feet of earth over their bomb-proofs was insufficient protection from the shells of the Japanese 11-inch siege mortars. A projectile from a 12-inch U. S. coast-defense mortar, fired inland, has been known to penetrate 30 feet in natural compact earth before exploding. Fortunately guns of this size are few and are generally available against selected points only, and therefore would not be used for the bombardment of long lines of field-works. A parapet thickness of 12 to 15 feet of earth and overhead cover of about six feet will protect against ordinary explosive shell from field pieces, unless the bombardment be concentrated or long continued.

Shrapnel is used mainly against the *personnel* of an enemy, as is the explosive shell against his *matérial.* At a range of 3000 yards on level ground a burst of shrapnel covers an approximate ellipse about 20 yards by 150 yards, or 2350 square yards, the longer dimension lying from front to rear. (Fig. 10.) The distribution of the bullets and fragments, or *splinters,* over this area is not uniform, the end nearest the enemy receiving the greatest number. The major axis of the beaten zone decreases with a greater or a less range. It also decreases as the slope is tilted *towards* the enemy, and increases on a reverse slope, similarly to the beaten zone of rifle fire. Its width remains unchanged except as affected by the height of the burst. Shrapnel splinters and bullets cause badly lacerated wounds, but they will not penetrate a steel helmet, the pack on a man's back, nor a six-inch layer of well-

compacted earth as overhead cover. Troops well entrenched have nothing to fear from shrapnel. The angle of fall of shrapnel bullets is so steep, 18 degrees

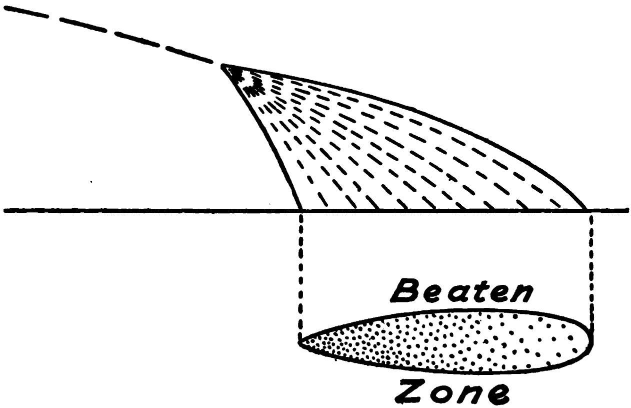


FIG. 10. A BURST OF SHRAPNEL

with the horizontal, that any trench designed to resist it must be deep and narrow, or must be provided with some form of overhead cover.

Against entrenched troops shrapnel is not effective, and high explosive shell must be used to demolish the works and get at the men. In Europe it has been found that men are killed by the back blast of a shell, without being touched by its fragments. This is guarded against by throwing up an embankment in the rear as well as in front of the trench.

CHAPTER VIII.

FIELD FORTIFICATIONS.

Fortifications are defined as "any engineering devices for increasing the fighting power of troops in the field." That which protects our troops from the enemy's fire, or simply conceals them, which assists our maneuvers and communications, or hinders and obstructs his, which is useful to us or destroys what is useful to him, will increase our fighting power. Intrenchments, screens or blinds, obstacles, communicating trenches, mines and demolitions, all come under the head of fortifications. Of these, by far the most important are those which afford protection from the enemy's fire and incidentally provide concealment and means of intercommunication. The term fortification, as usually employed, refers to works of this character only.

Field works may be considered as to:

1. Location, or siting.
2. Trace, or ground plan.
3. Construction.
4. Concealment.

LOCATION OF FIELD WORKS.

The location of trenches is affected by: first, the general line to be occupied, second, tactical considerations and features of the *terrain*.

The general line to be held is determined by the commander of the field forces, and depends upon strategical considerations. Subordinate commanders may exercise considerable latitude in the local siting of works, so long as they do not depart from the general

line, mask the fire of other organizations, nor introduce dangerous salients or re-entrant angles into the line.

Troops who will occupy a line of trenches, therefore, endeavor to fit them to the terrain, so as to provide concealment, reduce the work of construction, or to augment the effectiveness of the works. Tactical considerations, such as actual or potential interference by the enemy with the construction, may affect the location.

Works for the defense of a position should provide concealment, a clear field of fire to the front, good communications to the rear, and the flanks must be made secure, either by resting upon some natural obstacle, as a river, swamp, cliff, etc., by contact with adjacent troops, or by proper construction. A clear field of fire to the front was formerly considered all important, to be secured, if necessary, at the expense of all other considerations. With the greatly increased effectiveness of modern artillery, however, it has been accepted as a general maxim that "that which is seen is as good as destroyed," and concealment of the works becomes of prime importance. Improvement of small arms, machine guns, and the wire entanglement render more certain the stopping of an attack in the final 100 yards. In this portion of the immediate foreground, therefore, it is important that no part be screened from the fire of the defense by vegetation, buildings, or topographical features. Vegetation and buildings may be cleared away, gullies and hollows filled and slopes pared down, but much of this labor may be avoided by proper selection of a site. In Fig. 11, a position at the military crest, B, commands *all* the foreground, while one at the topographical crest, A, leaves considerable *dead space,* where the enemy may collect in safety and rest for a final dash up the hill. Furthermore, the latter position brings the works

into relief against the sky, where they are plainly visible to the enemy.

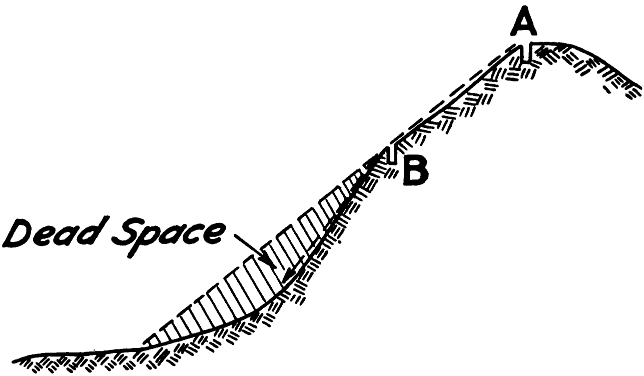


FIG. 11. TRENCHES AT MILITARY AND TOPOGRAPHICAL CREST

But even the position at the military crest may not be the best. It is advantageous because of its *command* or elevation, and the greater visibility of the field of fire thus secured; because the enemy will have to climb to reach it; and because it usually offers better communications to the rear. But it may be exposed to artillery fire up to the last minute of an attack, without danger to the enemy's infantry; shots fired from this position have a very short danger-space and small beaten zone; and if the military crest is near the top, a large percentage of *overs* may graze the crest and reverse slope, with danger to the supports and reserves in waiting there. A trench at the foot of the hill, B, Fig. 12, affords a grazing fire to the front with a long danger space, so that attacking lines of infantry cannot follow one another closely; the enemy's artillery cannot support the attack to its last stages without danger

to his own men; and complete concealment is usually easy to effect, so that the position is disclosed only when fire is opened by the defenders. A line of dummy

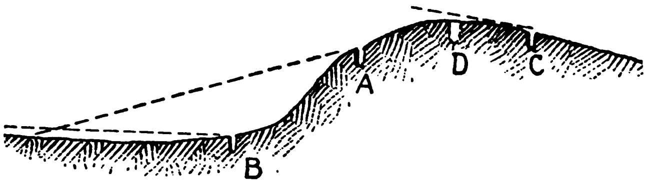


FIG. 12. TRENCHES AT FOOT OF SLOPE, MILITARY CREST AND IN REAR OF CREST

trenches, D, at the military or topographical crest will tend to draw the enemy's artillery fire away from the true position. The one disadvantage of this location is the communications to the rear, which may have to be effected by the digging of zig-zag trenches, traversed so as to be safe from enfilade fire. These, in turn, are difficult of concealment.

Some authorities advocate a double or multiple line of fire, as at A, B, and other points on the slope towards the enemy. This permits an increased volume of fire per unit width of the position, but the trenches must not be relied upon as successive lines of defense. If the first line is carried, its retreating occupants will mask the fire of the rear trenches.

The plan of placing trenches in rear of the crest, C, Fig. 12, is proposed as affording a complete concealment from observers who could direct an effective artillery fire upon the position. This plan, it is argued, allows too much dead space in the immediate front, so that the enemy may advance in perfect security to close range at the crest of the hill. Its advocates, however, claim that fire action at the mid-ranges, 300-600 yards, is impracticable during an infantry attack

properly supported by artillery, however clear the field of fire, and that in this position, the defenders do not suffer from the preliminary bombardment, and still have about 100 yards in which to stop the enemy, besides the advantage of a heavy fire at close range, delivered unexpectedly. Experience in the present war appears to justify this contention.

TRACE OF FIELD WORKS.

The ground plan of a work must be laid out to fit the terrain. Its location must not interfere with the fire from other trenches, nor must its fire be masked by their location. The line follows roughly the contour, stepping back in *echelon* at bends, as a low point in the line, like a salient angle, particularly invites attack.

In the general line to be occupied, there will be certain points more suited to strong defensive works than others. These become the skeleton, which is completed by filling the intervals with connecting trenches. The plan is extended by the construction of *Points-d'Appiu,* or supporting points, which are designed for all round defense, and are located close behind the main line of trenches, to offer a stubborn resistance and break up any attack which may penetrate the trenches. A work of this character, with a closed trace, is known as a *redoubt* or *ring-trench.*

When high parapets were the rule in fortifications an enemy who gained the protection of the outer wall was about as safe as the man inside, so the lines were traced with projections to the front and at the corners of closed works, known respectively as *salients* and *bastions,* from which the *curtain,* or line of connecting parapet, could be swept by a flanking fire. This form still survives, changed by the increased range of small arms, in the line of strongly fortified points, connected by curtains of fire trenches.

Fig. 13 shows a portion of a company trench designed for one squad, allowing one rifle per yard of front. The splinter-proof in the rear is for the purpose

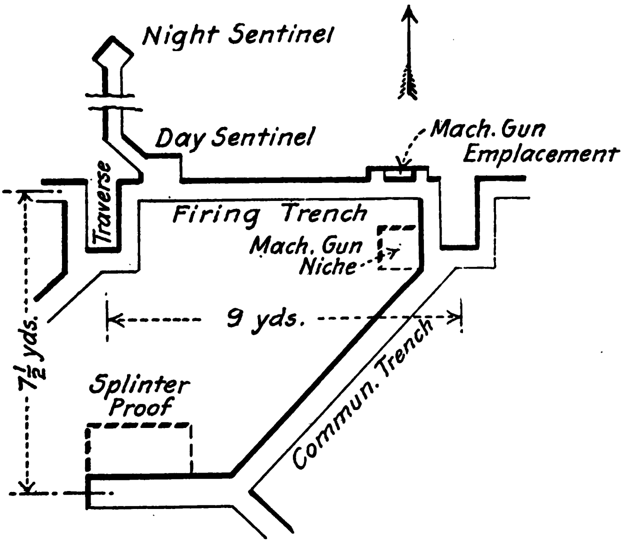


FIG. 13. SQUAD TRENCH

of sheltering the squad, excepting the sentry or lookout, during a shrapnel bombardment. In Fig. 14 is shown the complete company trench occupying a front of about 125 yards, with firing, communicating and cover trenches, splinter and bomb proofs, and dressing stations.

The flanks of a trench should not be *refused* as in Fig. 15 (a). The men in this flank trench lose all fire to the front, are exposed to enfilade, and are useless except in case of a flank attack. In (b) the trenches

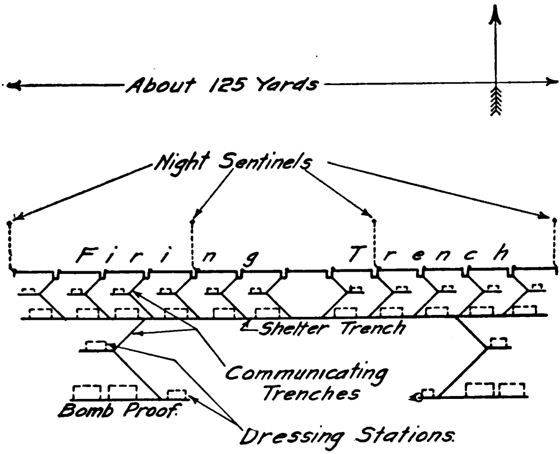
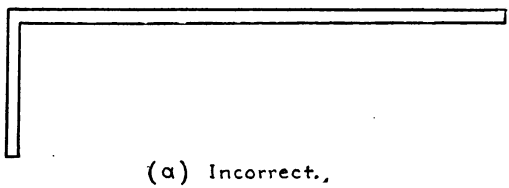


FIG. 14. COMPANY TRENCH



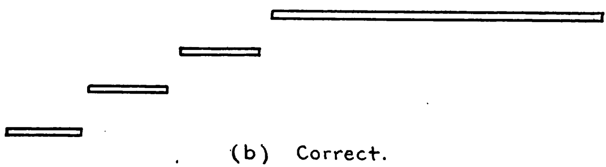
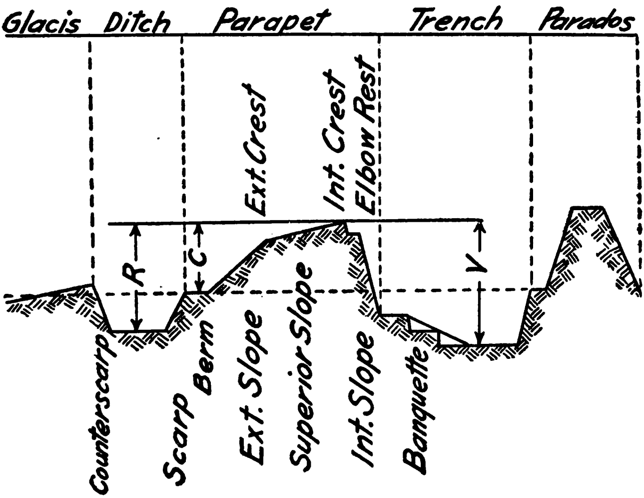


FIG. 15. FLANK OF A TRENCH

are stepped back in *echelon,* and each subdivision may fire to the front or towards the flank.

CONSTRUCTION OF FIELD WORKS.

Parapet. The typical form of parapet is shown in Fig. 16, with the parts named. This form is practically obsolete, and is shown only to give the nomenclature. The present tendency is to dispense with the ditch, lower or surpress entirely the parapet to aid



R=relief, C=command, V=vertical cover.

FIG. 16. TYPICAL PARAPET

concealment, and to deepen and decrease the width of the trench to afford increased protection from artillery fire. The *banquette,* formerly a slope up which field pieces were rolled to place them in action, is now constructed in steps, as artillery is no longer grouped with the infantry.

In permanent works, *counterscarp galleries* are sometimes built in the outer wall of the ditch and connected with the trench by tunnels under the parapet. These galleries are occupied by men who enfilade the ditch and fire into the backs of such of the enemy as penetrate this far. The position of the *exterior crest* prevents these men from firing into or being reached by the fire of the defenders in the trench. A better device is the *caponiere,* which is a low gallery built transversely across the ditch, with its roof slightly above the bottom of the latter, and the upper part of its walls pierced for rifle fire along the ditch. This structure is directly connected through the parapet with the trench.

The *parados* was formerly constructed only when reverse fire was anticipated, as in closed works, but the present war has proven it of great value in concealing embrasures and loopholes, through which otherwise light would show, in supplying a background which renders the regular shape of the parapet less conspicuous, and in protecting the occupants from the blast of high explosive shell bursting just in rear. Trenches are frequently built with a substantial parados and no parapet.

Revetments. The interior slope must nearly always be revetted. These revetments are of many varied types. For more deliberate works, *gabions,* which are large cylindrical baskets, woven without ends and earth filled, are largely used. In permanent works masonry and concrete are common. In the field, however, revetments must be improvised from the materials at hand. *Sand bags* are probably the most popular, as they will not splinter under fire and afford more flexibility in their use, but stone, logs, planks, sod. brush *fascines* and *hurdles,* and even steel sheet piling all find their use.

For *crowning* a parapet, some material which will

not splinter, as sod or sand bags, must be used. The former is cut rather thick and built up as ashlar masonry with alternate *headers* and *stretchers*. Sand bags are laid up in a similar manner, but must not be filled to a too plump form. They must be laid with a shove-joint, in order to close all crevices, and the tied ends, or *chokes*, and the seams, must be laid *in the parapet*. *Logs* and *planks* are cut to the height of the interior slope, their ends placed behind a foot log in a shallow trench, and their tops secured by a waling piece which is anchored to stakes buried in the parapet. *Poles* are laid horizontally behind vertical stakes, whose lower ends are driven in the ground and whose tops are anchored to stakes in the parapet as described above. *Fascines*, or bundles of brush, are treated similarly. *Hurdles* are woven sheets of basket work, like a gabion rolled out straight. They are secured by driving their vertical stakes into the ground and anchoring their tops. Hurdles are particularly adapted to the revetment of trenches in unstable earth, provided it will stand long enough to complete the excavation.

Traverses. A trench is protected from *enfilade*, i. e., from a flanking fire which rakes the trench from end to end, by offsets known as *traverses*. (Fig. 17a.) In order to afford a maximum development of the firing line the trench is sometimes offset to the front, but this type does not meet with much favor. The best form is the *detached traverse*, with a firing trench in front and a passage in rear, from which the communicating trench leads. Besides intercepting enfilade fire, traverses tend to localize the effects of a shell bursting in the trench. The traverse should be high enough to protect not only the trench, but the heads of men firing over the parapet. It should not, however, be higher than the parados. Fig. 17 (b) shows the effect of a bend in the trench, exposing a portion to flanking fire. This may be remedied by a longer traverse, a shorter

distance between traverses, a recess at the point exposed or a parados. The present tendency is towards a wider traverse than heretofore, owing to the use of

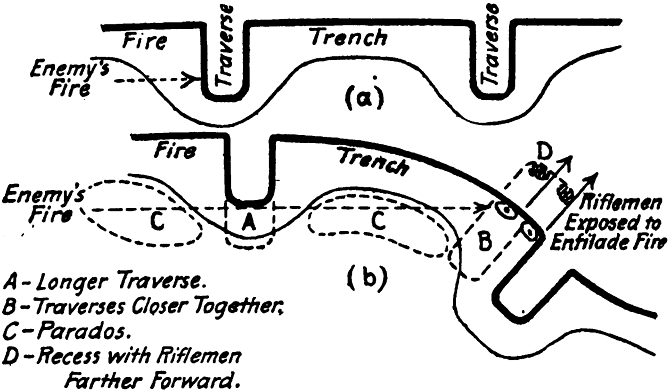


FIG. 17. PROTECTION FROM ENFILADE

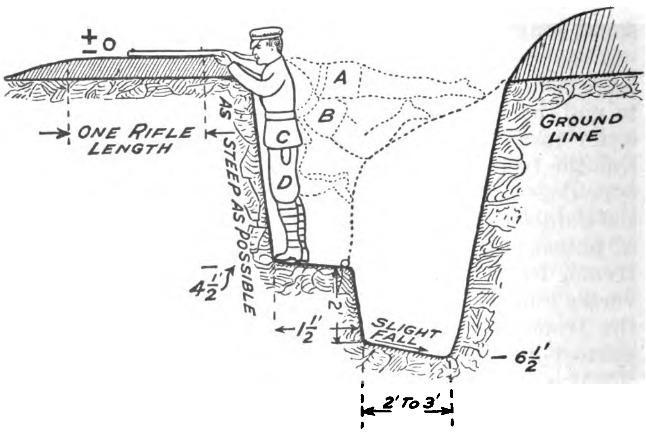
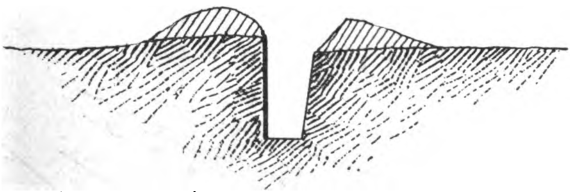


FIG. 18. DIGGING IN UNDER FIRE

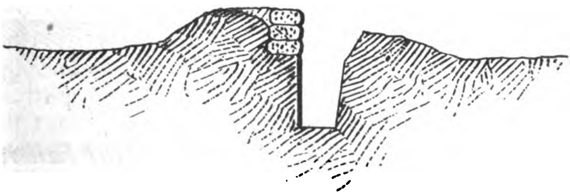
high explosive shell and machine guns. The latter can cut down an ordinary traverse in a few minutes, especially if not revetted. The space under a traverse, which cannot be reached by the enemy's fire, is sometimes hollowed out and used for a magazine or store house.

Firing Trenches. In the operation of *digging in* under fire, the soldier first excavates a shallow prone trench, deepening it successively to a kneeling and a standing trench, the final step being the construction of a passageway in rear, through which a man may pass without disturbing the troops firing and without exposing his head over the parapet. (Fig. 18.) A prone or kneeling trench should not be contemplated for a moment except as steps towards a standing trench, as they are utterly useless against shrapnel.

In Fig. 19 (a) a common error is illustrated. The parapet is *not* bullet-proof, and the rifleman is exposed



(a) Incorrect.



(b) Corrected.

FIG. 19. BULLET-PROOF PARAPET

to a plunging fire, as from shrapnel or infantry at long range, from his belt buckle up. The interior slope must be revetted, and straightened up so as to increase the top thickness of the parapet and to afford cover to the rifleman to the height of his shoulders. (Fig. 19-b.)

Fig. 20 shows a plain standing trench of low parapet.

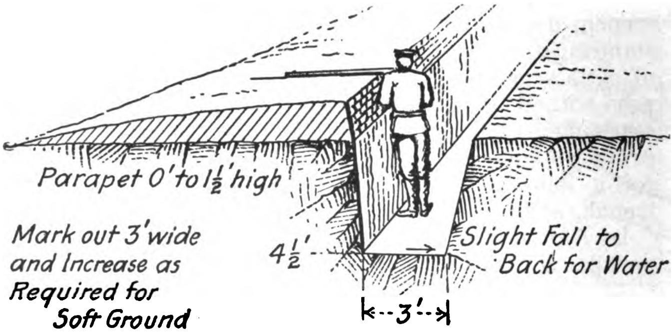


FIG. 20. STANDING TRENCH

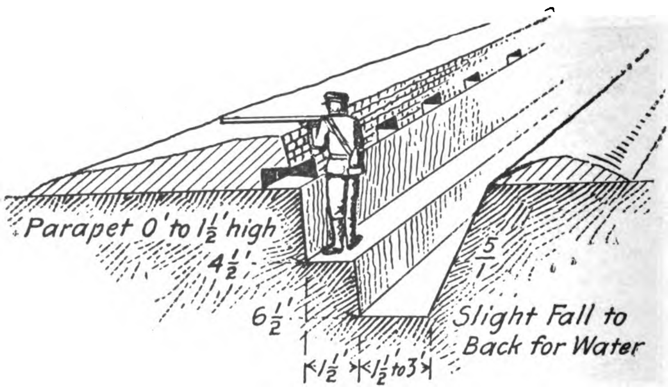


FIG. 21. STANDING TRENCH WITH PASSAGE

Fig. 21 shows the same with the addition of a passage. This latter may be excavated under fire, with the occupants of the firing step in action. The recesses in the parapet are for spare ammunition.

In Fig. 22 the parapet is entirely surpressed and the earth wasted. The firing step is replaced by a platform, allowing space underneath for resting or storage.

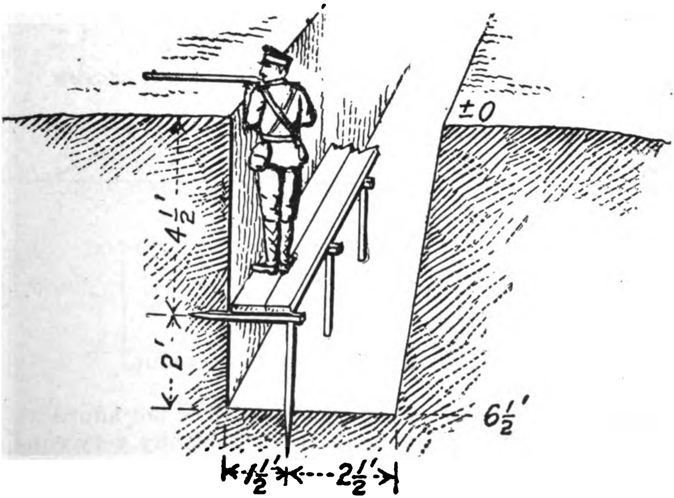


FIG. 22. FIRING TRENCH WITHOUT PARAPET

Fig. 23 is a development from a series of individual rifle pits, a connecting trench having been dug along their rear. In addition to the traverses formed by the recesses, which protect the men firing from enfilade, the passage trench itself should be traversed, to protect those using it.

Head Cover. Against a heavy fire the types of trenches described would not afford sufficient protec-

tion, and some form of head cover must be adopted. This may be formed by *crenellating* the parapet, forming notches or *embrasures* through which to fire, or by the construction of *loopholes,* which are embrasures

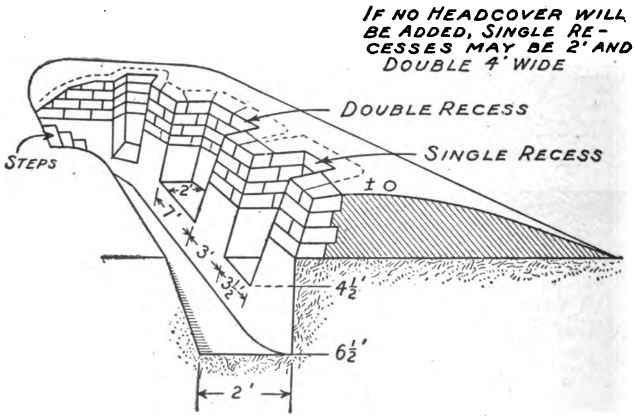
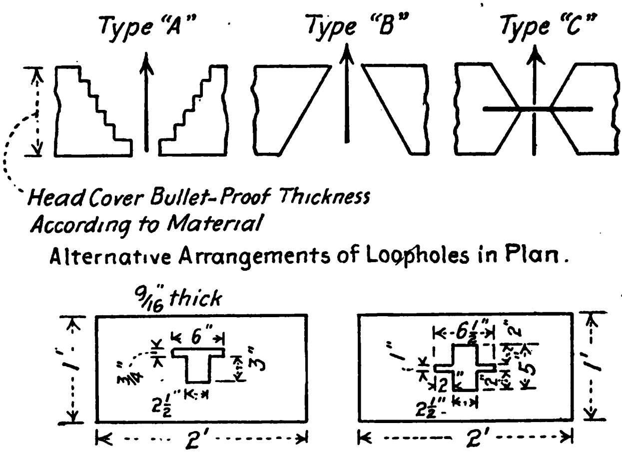


FIG. 23. RECESSED FIRING TRENCH

roofed over. A crenellated parapet does not afford as good protection as loopholes, and is usually very conspicuous, unless viewed against a high parados as a background.

Fig. 24 illustrates types of loopholes. In A a wide opening is presented to the enemy, but the rifleman has a large angle of fire with small movement on his part. The cheeks of the loophole must be stepped as shown to prevent bullets glancing in through the *throat*. In B a small opening is exposed to the enemy's view, but the rifleman must change his position considerably to alter his line of fire to any appreciable extent. Fewer men per given length of trench could be used with such loopholes than with those of the A type. In C is

shown a compromise of the two types. A steel plate, cut out as shown, is usually placed in the throat of loopholes of the C type. Loopholes should be screened if light may be seen through them, as otherwise the



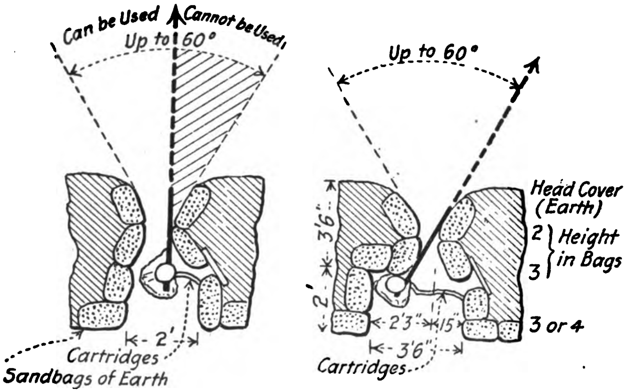
Steel Loopholes in Plates.

FIG. 24. TYPES OF LOOPHOLES

obscuring of an orifice means a head behind it, and the enemy's sharpshooters will learn the location of the holes and fire when the light is cut off.

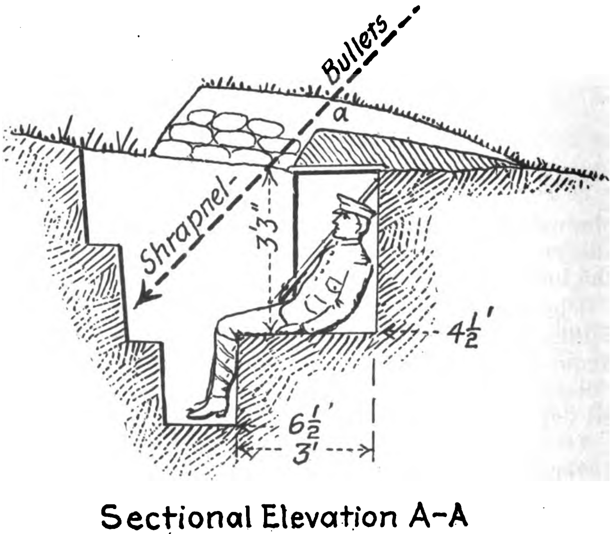
Fig. 25 shows a common error of the individual soldier in constructing a loophole and how it may be avoided. It is usually necessary to examine all loopholes built by enlisted men and see that an unobstructed field of fire in the proper direction is afforded.

Overhead Cover. Under shrapnel bombardment head cover alone is insufficient, and overhead cover must be provided. The simplest form is that prepared by the



Incorrect. Correct.

FIG. 25. LOOPHOLE CORRECTED FOR WIDE ANGLE OF FIRE



Sectional Elevation A-A

FIG. 26. INDIVIDUAL OVERHEAD COVER

individual soldier, Fig. 26. Boards are laid on the ground and covered by the parapet as the excavation of a plain standing trench proceeds. The niche is finally scooped out under the boards. He occupies this recess during an artillery bombardment and uses the standing trench for firing. Fig. 27 shows a somewhat

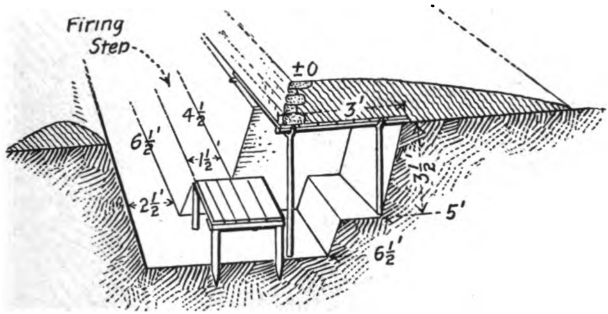


FIG. 27. PARAPET SHELTER

more elaborate form, designated a *parapet shelter*. The wooden platform provides a continuous firing step. Such overhead cover contains from one to two feet of earth and is known as a *splinter-proof*. A *bomb-proof* is built to resist high explosive shell, and is roofed with heavy timbers covered with six to twenty feet of earth. Broken stone covered with earth is also used for overhead cover.

The highest type of firing trench is one completely roofed over by splinter-proof construction, loopholed to the front, and accessible by stairs or communicating trenches to the rear. (Fig. 28.)

Firing trenches which are liable to be rushed, or from which a charge is to be made, must be constructed without head or overhead cover. Otherwise the troops will find it impossible to leave the trench in a body to

make a rush, and they will be caught like rats in a trap by a successful charge of the enemy. A man in even an open trench is at a considerable disadvantage

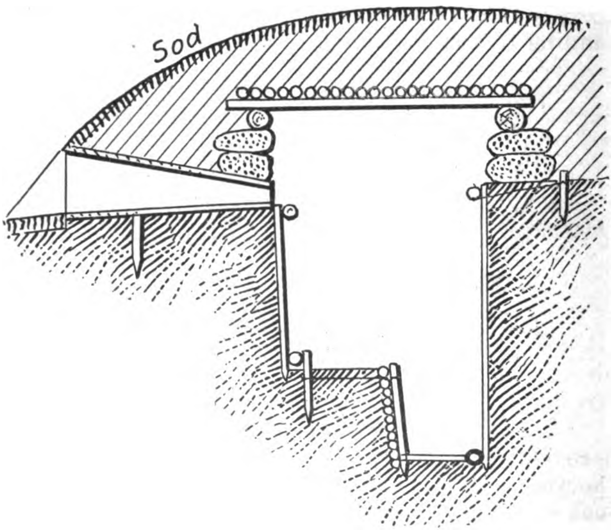


FIG. 28. FIRING TRENCH WITH OVERHEAD COVER

against an enemy with a bayonet who reaches the crest above him, but if inclosed by overhead cover, the entire garrison of a trench may be annihilated by hand grenades thrown through the loop holes. The Japanese battle regulations specify that the defender shall not await the final rush to the edge of the trench, but shall leave his trench and counter-charge with the bayonet as soon as the obstacles are passed. Egress from firing trenches to the front may be facilitated by digging a couple of steps in the front face and setting a stake in the parapet, to be grasped by the hand in climbing

out. Unless some such device is constructed, much valuable time may be lost in commencing a charge.

Cover trenches are provided for troops in reserve, and may be entirely inclosed, with no facilities for firing, and connected by communicating trenches with the firing line. (Fig. 29.) In a cover trench occupied

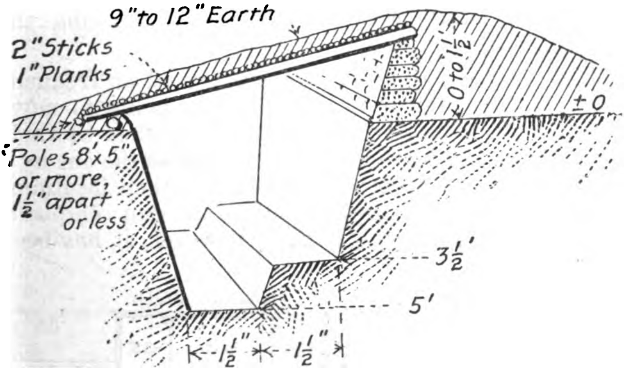


FIG. 29. COVER TRENCH

by troops on duty only, as in a combined fire and cover trench, six square feet of floor area must be allowed for each man. For more continuous occupancy, twelve square feet, and for habitation of long duration, eighteen to twenty square feet, are required. The thickness of overhead cover required depends upon the nature of the fire it will have to resist. It may vary therefore from a splinter-proof roof one foot thick to a bomb-proof of any desired depth. Points whose protection is of the greatest importance, as telephone central stations and posts of important commanders, may be placed from thirty to forty feet underground.

Communicating trenches are constructed in zig-zags

to prevent enfilade, and lead from the cover to the fire trenches. They are built very narrow and deep, with passing points hollowed out of the walls at frequent intervals. The excavated earth is piled up on both sides, to reduce the amount of digging, and at the junctions of the diagonals are located short stretches of trench (returns), in which are located the first-aid dressing stations and the sanitary arrangements. All earth must be disguised to resemble the surroundings.

Machine gun emplacements are located at frequent intervals along the line, the intention being to move the guns from one emplacement to another as their effectiveness can be thus increased, and as the enemy's fire becomes too severe for them in other locations. Fig. 30 shows a typical machine gun emplacement. When this type is used, however, it has been

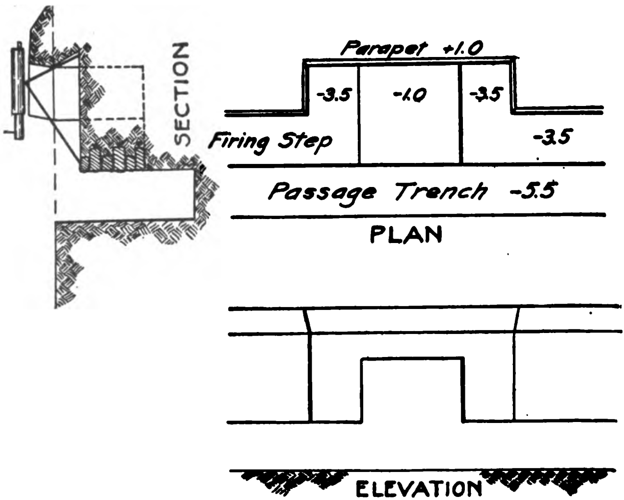


FIG. 30. MACHINE GUN EMPLACEMENT

found that the enemy will concentrate his fire upon the machine guns and put them out of commission at the first. The method now recommended is to place the

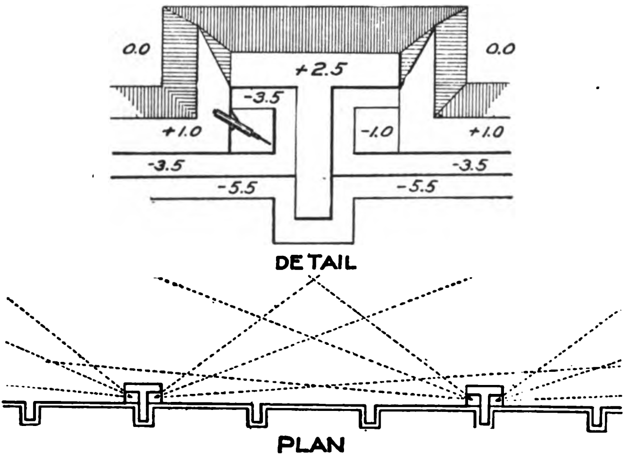


FIG. 31. MACHINE GUN EMPLACEMENT FOR CROSS FIRE

machine guns behind a strong parapet, with no facilities for frontal fire. From behind the flanks of this protection, which is only slightly higher than the firing parapet, they cover the space between emplacements by a cross-fire. (Fig. 31).

Gun cover is secured by two methods, *epaulments* and *pits*. In the former, a low parapet is constructed in front, to fill the space between the ground and the gun shield, higher embankments on the sides, and trenches in the rear for the gun crew. A trench is usually provided for the ammunition, of which a large stock must be on hand if a heavy fire is to be maintained. If the fire is to be delivered at a high angle, the gun may be sunk into the ground, and a long slop-

ing trench dug in prolongation of the barrel. The excavated earth is piled on the sides, as the shield usually suffices for frontal cover.

CONCEALMENT OF FIELD WORKS.

Concealment is now considered of prime importance in the location and construction of field fortifications. In fact, troops that are well hidden from the enemy are probably safer than those which are sheltered in strong works but still under his observation.

Disguising.

The sky line must be avoided, as it is practically impossible to treat the outlines of the parapet so as to disguise its real identity. Also, regular outlines and particularly the abrupt ending of a parapet, tend to betray the position of a work. A safe rule to be followed is that the natural appearance of the terrain is to be changed as little as possible. Concealment is therefore facilitated by surpressing the parapet, making it conform to the general shape of the ground, and narrowing the trench on a forward slope, so that its rear edge is not visible over the parapet. Sod over the space which will be occupied by the trench and parapet should be removed and carefully replaced over the complete parapet, so as to hide the fresh earth. This is best accomplished by cutting the sod in strips and rolling it towards the enemy, afterwards rolling it back over the parapet. In this connection it should be remarked that the mere covering of the parapet with material of the same color as the surroundings does not necessarily conceal it, as its apparent color to the enemy may appear quite different when viewed on the steep slopes of the parapet and on the adjacent level ground, owing to the varying light reflections.

The transplanting of small trees, bushes, etc., which

must be placed in front of rather than on the parapet, will aid concealment, but the scattering of leaves, branches, etc., over the earth, or the sticking of limbs of trees into it, are worse than useless, as the fresh vegetation soon withers and renders the position more conspicuous than before. Dead leaves, twigs, etc., are excellent, provided the surrounding earth is covered with the same material. It goes without saying that neighboring patches of ground should not be denuded of sod and rendered highly conspicuous in order to provide covering for the parapet.

Dummy Trenches are a very useful adjunct to concealment, as directing the attention of the enemy away from the occupied works. They are most effective when they present the appearance of real trenches ineffectually concealed rather than excavations made without any attempt at hiding them. In short, the enemy's attention must not be too expressly invited to them. The turning over of a two-foot strip of sod, with perhaps a foot of excavation at the rear edge, will usually be sufficient. Dummy trenches must not be placed where fire directed at them will endanger the true position.

Dummy artillery positions are sometimes prepared with considerable care, and are very effective when the details are well carried out. According to a recent British publication, an excellent Quaker gun may be made from a section of a telegraph pole and the fore truck of a farm wagon, with boards for gun shields. If at intervals a couple of ounces of gunpowder are placed on a tin shelf at the muzzle, and fired electrically, especially at the same time a real gun is fired elsewhere, the enemy may be tempted to waste many rounds of perfectly good live shell.

Concealment from Aerial Observers. It has been found from the present war that nearly all trenches are easily visible to the enemy's air scouts, but if care has been taken to remove from the adjacent ground all

prominent marks by which the observer can locate the trenches to the gunners, the latter will have considerable difficulty in getting on the target from the observer's description. All prominent trees or clumps of vegetation, buildings, light-colored rocks, wind-mills, etc., that might thus serve as reference points should be avoided in locating the trenches, or cleared away from the vicinity.

While the trenches are usually seen without difficulty, it is hard to determine, from the height at which the reconnaissance must be made, whether or not they are occupied. The straw which is sometimes placed in the bottom of trenches to protect the feet of the men from wet ground adds greatly to their visibility and aids in ascertaining their occupancy. The paths which may be worn to a trench or more particularly to a gun position often result in the betrayal of a work which would otherwise escape notice. Also, the absence of such paths to an otherwise obvious gun position may proclaim the latter as a dummy.

CHAPTER IX.

OBSTACLES.

Fire action alone will not stop a determined enemy. It has been found that troops will not remain to meet a charge if it advances too close for comfort. Therefore some obstacle must be presented to an advance beyond a certain point. Natural obstacles may be taken advantage of where encountered, but these are not plentiful, and are seldom situated where they can be effectively used.

Obstacles must not be constructed as part of the defensive works of a position without the authority of the officer commanding the section of line, as they may interfere seriously with contemplated movements of the defending troops, when a change is to be made to the offensive. Furthermore, obstacles should not be made continuous along the entire front, as they will prevent counter-attacks and the resumption of the offensive by our own troops. The gaps are swept by concentrated fire from machine guns and specially designated units. When openings are left in this manner, the way of approach of the enemy is in a measure predetermined, as attacking troops will always crowd towards the gaps. Care must be taken that works otherwise well concealed are not betrayed by the obstacles erected to protect them.

Barrier Obstacles. To be effective an obstacle must be concealed from the enemy, it must not afford any cover to an attacking force nor obstruct the fire of the defense, and it must be difficult of destruction. Obstacles are best located at a short distance in front of the parapet. This distance varies considerably as

recommended in the service manuals, 50 to 100 yards being usual, but with the short field of fire allowed by approved practice in the present war, this figure may be materially reduced. Some photographs of actual works shows the obstacles placed against the parapet. It is said, however, that such close proximity is objectionable, as it permits the enemy's grenade throwers to approach at night and bombard the trench.

Some types of obstacles are shown in Fig. 32, which is reproduced from the Engineer Field Manual, U. S. Army. The *abatis* consists of large branches of trees, which are trimmed of all foliage and small limbs, their ends sharpened, and then laid in several rows, the pointed ends towards the enemy. The butts are firmly staked down and barbed wire is interlaced among the branches. An abatis is easily destroyed by artillery fire unless concealed in a natural depression or a ditch. It may also be protected by raising an embankment in front of it, with a long sloping glacis towards the enemy.

A *slashing* is a quick substitute for an abatis, made by cutting trees nearly through and felling them towards the enemy. This, however, is liable to afford too much cover to the attack unless swept by cross-fire.

A *palisade* is a strong fence. It must not be made of poles large enough to give protection to a man, and it must be securely set in the ground. This is best accomplished by burying the butts of the poles in a trench, with stone wedges between the butts and log waling pieces on one or both sides. A waling piece above ground assists materially in scaling the obstacle. but strands of barbed wire at the top add to its effectiveness.

A *fraise* is a horizontal palisade or wire fence built out from the scarp or counterscarp of a ditch.

Roads may be closed, especially against cavalry, by *chevaux de frise,* which are obstacles built in "saw-

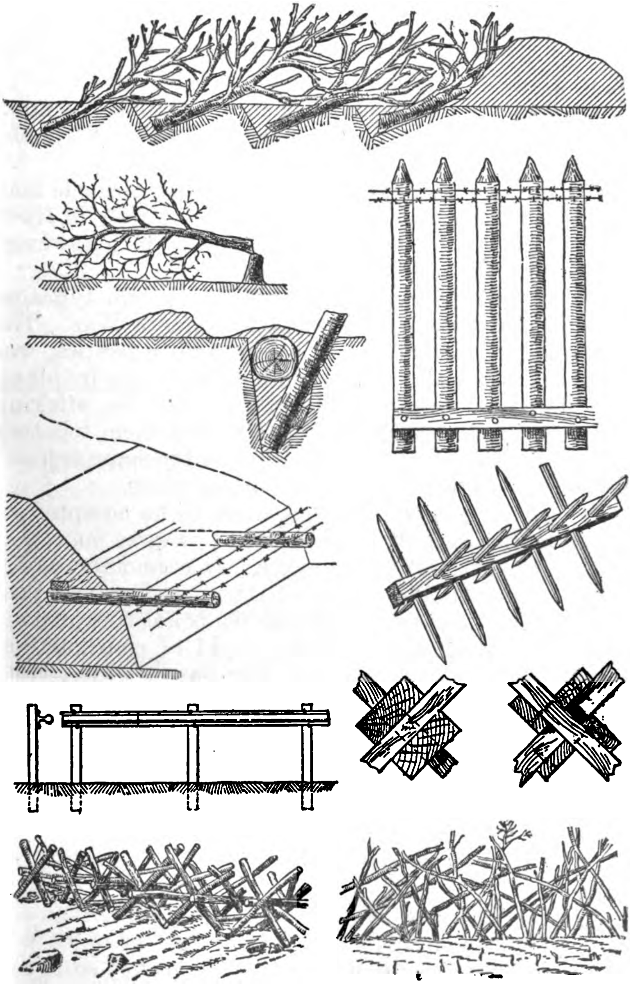


FIG. 32. OBSTACLES

buck" form. They are constructed in sections and chained together. The figure shows how they may be built up of dimension lumber. Cavalry may also be stopped by setting railway ties in the ground and spiking a rail along their tops four or five feet from the ground.

If the topography permits, a very good obstacle may be formed by flooding the ground immediately in front of the works. This may be impracticable, however, on account of the labor involved.

At the bottom of Fig. 32 are shown two types of obstacles used during the Russo-Japanese War. The Russian type, consisting of heavy timber trestles, was prepared behind the lines and carried out in place. The Japanese obstacle was constructed by sticking light poles into the ground and wiring them together where they crossed, or by treating in the same manner the trunks of young trees growing in place.

The *wire entanglement* has come to be accepted as the standard form of obstacle, and possesses many advantages over most other types. It cannot be easily destroyed by artillery, it is extremely difficult of passage, affords no cover to the assault, is not conspicuous at any distance, and is fairly rapid of construction. Fig. 33 shows a common type, two panels wide. Note the great difference in the size of the openings left by staggering the center row of posts as against placing them rectangularly. The wires must be strung loosely, as they are thus less easily cut by blows from a bayonet or machete. No horizontal wires are placed on top, so that any attempt at crossing the entanglements on planks or ladders will be defeated by their tipping over.

In the European War, it has been found that the noise of driving posts for entanglements at night will draw a heavy fire upon the working party, so it has been the practice to construct wooden forms or trestles

inside the works, string them with barbed wire, and place them in position at night. They are chained or lashed together, and are sometimes anchored back to the trench, to prevent the enemy's hauling them away by means of grapnels.

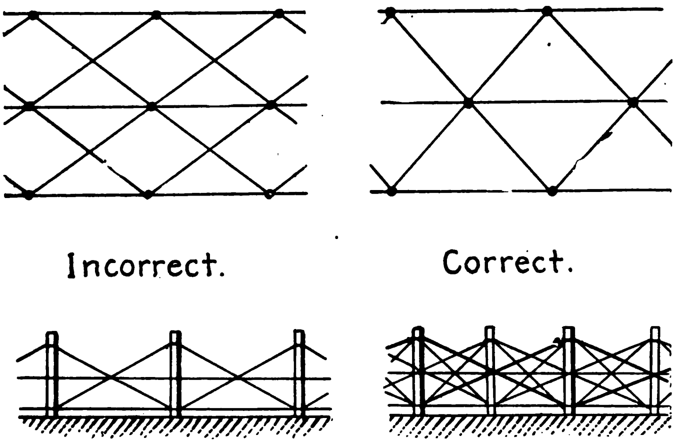


FIG. 33. WIRE ENTANGLEMENTS

Destroying Obstacles. Wire entanglements are destroyed by cutting the wires with clippers or bayonets, or by throwing a heavy grapnel over them by means of a trench mortar and hauling it back. A pole containing a chain of dynamite cartridges may be laid or thrown across the entanglement and the charges exploded. This will cut all the wires in contact with the pole, but little progress can be made in this way towards the destruction of the entire obstacle, and the opening of one passage will cause an attacking force to concentrate and offer an excellent target for machine guns.

An abatis or slashing is attacked by cutting the interlaced wires with pliers, opening up a way through the obstacle, and attacking it in the rear with axes. The branches may be easily cut from the rear, pulled out of the abatis and cast into piles. A long string of explosives on a pole, as described above, will be useful in effecting the first breach.

Palisades, fraises, and chevaux de frises are attacked by axes. They are more easily destroyed under fire than the other types described. At night, parties may pile brush around them and set it afire. Floods may be reduced by cutting the dam which backs up the water, if it can be reached, or by opening an outlet for the water to lower ground. When very low lands are flooded by cutting ocean dikes, as in Belgium, there is little that can be done except to attack with boats and rafts, by night.

Flares and Alarm Signals. As most attempts at cutting obstacles will be made at night, some form of alarm must be provided to warn the defenders. The best of these burst into fire and not only give a signal but illuminate the obstacles sufficiently to guide the fire of the defense. They are usually operated by *trip* or *cut* wires. The former operate by the enemy's pulling or tripping over them, the latter by being cut and releasing a weight, which, in falling, actuates the alarm. Some signals are arranged to operate either upon a pull or by the slacking of the alarm wire. The weight may be attached to a cord which will pull the trigger of a rifle, or may fall upon a cartridge. A shot, however, is not sufficient where shots are being constantly fired, and the same apparatus may be made to ignite a flare by inserting an instantaneous fuse in the cartridge and leading it to a heap of gunpowder in a prepared bonfire. The latter, if intended to remain for some time, must be roofed over with canvas or boards. Where entanglements are close, pieces of tin and iron

may be hung upon the wires, to rattle when disturbed. When the alarm has once been given, a flare consisting of a rag ball, wound upon a wood block, saturated with oil and rolled in gunpowder, may be fired from the trench by a gas pipe cannon, using a small propelling charge of powder. This will burn for a short time and disclose the nature of an attack. For more complete illumination, bonfires may be ignited from the trenches by electricity or an instantaneous fuse. They should of course be screened to prevent lighting up the trenches.

No form of automatic alarm must be allowed to take the place of alertness on the part of the defense.

Land mines are temporarily effective as an obstacle. They are planted in several lines and usually fired electrically by successive rows. A land mine proper is exploded as the enemy crosses it, a *fougasse* is arranged to blow stones in the face of a charging enemy. (Fig. 34). Mines must not be so heavily charged that

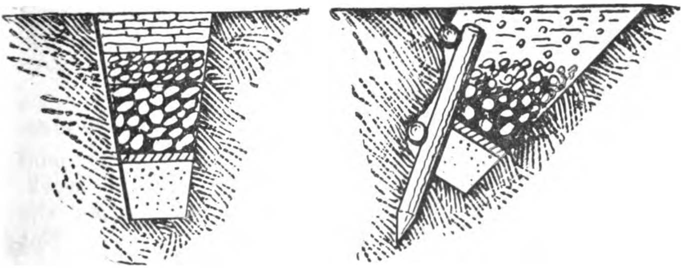


FIG. 34. LAND MINE AND FOUGASSE

their craters will offer cover to advancing troops, but *unless* the charge is heavy, their actual execution will be small. The effect of land mines, therefore, is mainly moral, it being difficult to send troops across a field known or supposed to be mined, or in which mines have been exploded. To determined troops, however,

they cannot be relied upon to furnish a permanent barrier.

Fig. 35 shows the explosion of a row of land mines laid by the engineers at the "Battle of Martins Mountain," during the Fishkill Plains maneuvers of the First Brigade, N. G. N. Y., season of 1915. The trenches in the foreground were occupied by the 71st N. Y. Infantry, part of the defending troops.

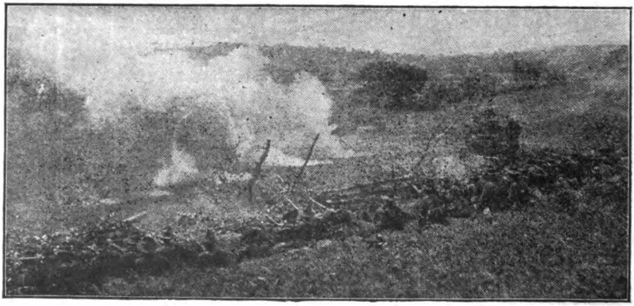


FIG. 35. LAND MINES

Table of Men, Time, and Tools *

REQUIRED FOR THE EXECUTION OF CERTAIN FIELD-WORKS.

Note.—Except where otherwise stated, the material and tools are assumed to be on the site of the work. All tracing and marking is to be done before the distribution of the working parties at the sites. Not more than five minutes should be consumed in distributing the men or in changing reliefs, if the men have been told off into suitable groups or parties under leaders previously instructed in the nature of the particular works in hand. One leader or foreman can conveniently supervise up to twenty unskilled men on earth-work.

*From the British Manual of Field Engineering

No.	Nature of Work.	Minutes of One Man	Per Unit of Task.	Suitable Unit Party.	Tools per Party.
	ENTRENCHING.				
1	Excavation only.	3	1 cub. ft.	1	1 shovel and 1 pick
2	Ditto, in small recesses, shelters, etc......	9	1 cub. ft.	1	Ditto
3	Shovelling loose earth	1	1 cub. ft.	1	1 shovel
4	Removing fifty yards (average) deposit, and return ...	2 1	1 cub. ft. 1 cub. ft.	1 2	1 barrow 1 stretcher
5	Filling sand-bags	3	1 sand-bag	3	2 shovels
6	Head cover, sand-bags or sods..	60	1 loop-hole	1	1 shovel
7	Overhead cover, added to head cover in a recess	60	1 rifle	1	1 shovel, 1 hand-axe
	REVETMENTS.				
8	Brushwood, rough or planks	1½	1 sq. ft. (Revetted)	2	1 bill hook, 1 mallet
9	Sand-bags or sack	3	1 sq. ft. revetted	2	....
10	Sods, building with		1 sq. ft. revetted	2	1 shovel or spade
11	Sods, provision of (for above)		1 sq. ft.	3	3 sharp spades
	CUTTING AND FELLING.				
12	Trees, felling, up to 12 in. diam.	1	1 in. of diam.	1	1 felling axe or saw
13	Woods, clearing of brushwood and small trees	2½	1 sq. yd.	20	10 bill-hooks 4 felling axes 4 hand axes, 2 saws 1 grindstone 2 whet-stones

No.	Nature of Work.	Minutes of One Man.	Per Unit of Task.	Suitable Unit Party.	Tools per Party.
	CUTTING AND FELLING.				
14	Hedges (felling stems)	10	1 yd. run	2	1 bill hook or hand-axe. 1 saw, 3 fathoms rope
15	Brick wall, notches in up to 18 in.	10	1 notch.	1	1 pick crow-bar, or mason's chisel and hammer
	OBSTACLES.				
17	Abatis, and wired (one strong row)	120	1 yd. run	20	As for item 13; also 2 mauls, 3 pr. pliers, 1 pickaxe, 1 shovel
18	Wire Entanglement	60	1 sq. yd.	3	1 bill-hook, 1 hand-saw, 1 maul, 1 pr. pliers, 1 pr. wire-cutters. 3 rag pads for gripping and straining wire. *In hard ground add*: 1 steel jumper 1 sledge-hammer

CHAPTER X.

SIEGE WORKS.

Investment of a fortified place is accompanied by various activities which, on account of the time required, have no place in ordinary field works. Siege operations comprise defensive cover for the attackers, mines for the destruction of the defenders' works and saps to bring the attacking forces within assaulting distance.

Sapping. A *sap* is a zig-zag trench approaching the point of attack. (Fig. 36). It may be *right-handed* or *left-handed,* according to whether it gains ground to the right or left; and *single* or *double,* according to whether it is driven by one man, heaping the excavated earth on the side nearest the enemy, or by two men working side by side, and heaping the earth on both sides. The latter is the usual form near the enemy, where both sides must be protected, and in this case the sap is pushed forward as a double trench, the tongue of earth between being removed by soldiers following the sappers, similarly to the progressive order of excavation followed in tunneling.

Sapping is begun from the *first parallel,* which is a firing trench established as near as practicable to the enemy's works. A sap should not extend more than about 100 feet without a change of direction, and each branch should cover the head of the preceding branch by overrunning it several feet. When a point five or six hundred yards from the enemy is reached the *second parallel* is constructed, and from this a heavy rifle and machine gun fire is kept up to protect the sapping

operations. The *third parallel* is placed about half way between the second and the point of attack, and an assault will usually be made from this location,

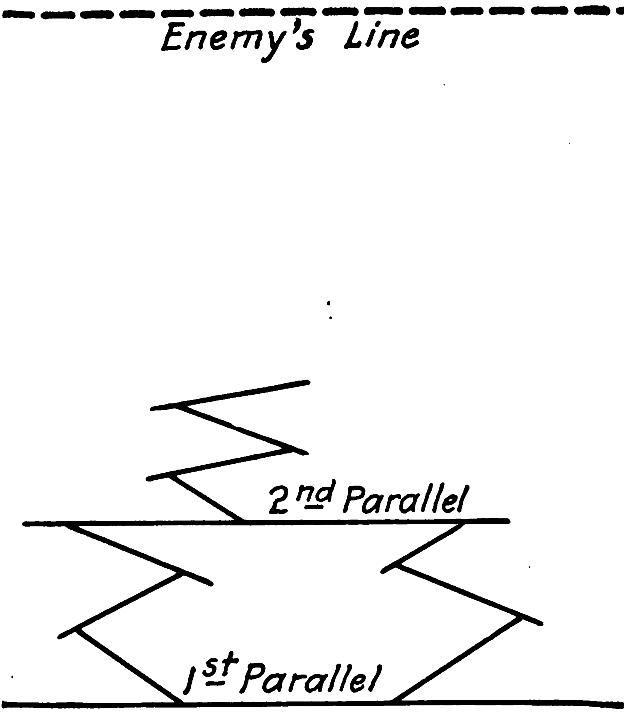


FIG. 36. APPROACH BY SAPPING

though it may sometimes be necessary to carry the work still further.

As the enemy's works are approached more closely, the inclination of the saps becomes flatter and flatter,

to avoid enfilade. Finally, protection must be obtained by rolling a pile of sand bags ahead of the sap and by the use of *overhead traverses.* These are constructed by placing boards across the sap and covering

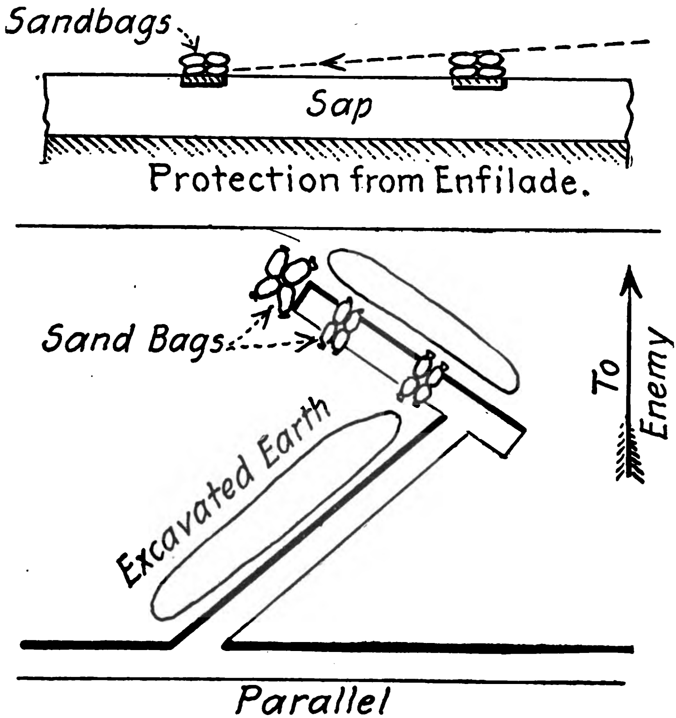


FIG. 37. A SAP

them with sand bags. They must be so spaced that a shot clearing one will be intercepted by the next. (Fig 37). This distance is made less as the work proceeds.

and finally the sap becomes a covered way. Further advance must then be made by mining operations.

Mining comprises underground approaches for the purpose of placing and firing charges of explosives under the enemy's works. A mine consists of a *shaft*, sunk vertically, and one or more *galleries*, driven hori-

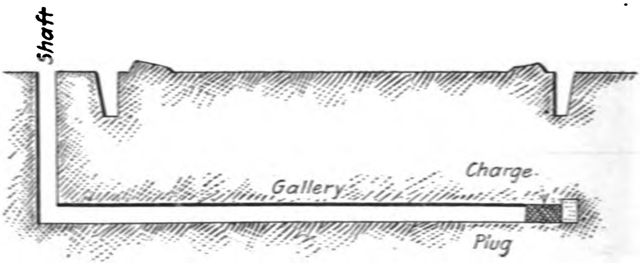


FIG. 38. MINE

zontally. (Fig. 38). If the gallery can be started from a ditch, bank or hillside, the shaft may be dispensed with, and much trouble avoided in carrying the alignment underground.

Mines must be driven in earth. Drilling and blasting operations are impracticable with the equipment ordinarily available, and the approach of the mine would be known to the enemy long before it was ready for use. Nearly all the work, therefore, must be protected against caving, and the timbering calls for all the skill of the miner and tunnel worker. Difficult soil is often encountered, and full sheeting of the shafts and galleries is the rule rather than the exception. Timbering is accomplished by the method of *frames and sheeting* if the earth is unstable, or by *cases* where it will stand long enough to allow their being placed in position. (Fig. 39).

The alignment of a mine involves quite complicated underground surveying, and must never be placed in charge of other than an experienced officer. For changes of direction *bevels* are made above ground

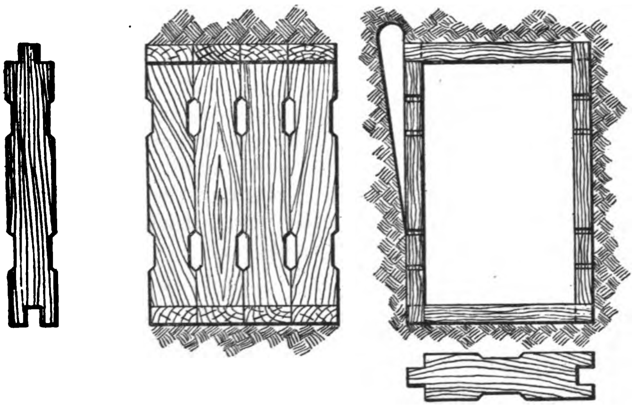


FIG. 39. MINE TIMBERING

from strips of board, and applied to the angle as laid out in the mine. In fact, the operations of mining, timbering and alignment conform so closely to civilian mining practice that it is usually sufficient to point out the purpose to be accomplished and turn the work over to officers and men experienced along this line.

When the mine is completed, the *charge* is placed, the officer directing the work being designated to perform this duty personally. The amount of explosive used must be sufficient, for while some is wasted if an overcharge is placed, it will *all* be wasted if the mine fails of its purpose from undercharging. The *plug*, usually of sand bags, is placed, and troops are massed in the last parallel for an assault. These troops rush

forward as soon as the mine is fired, occupy the crater and begin to entrench against a counter-attack. Engineers accompany the attack and assist in organizing the position for defense.

The only defense against mines is the *countermine.* (Fig. 40). The sound of working in earth can be heard for a distance of thirty to forty feet through the ground, even when care is exercised, and an alert enemy will have *listening galleries* driven out in front of his works and occupied by observers. When the approach of a hostile mine is detected, the listening gallery may be converted into a countermine by charging it and exploding it when the attacking heading comes within its *radius of rupture.*

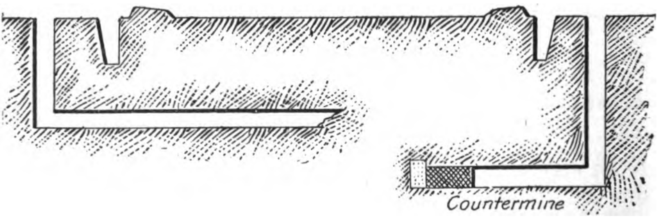


FIG. 40. COUNTERMINE

The usual aim in countermining is to blow in the *side* of the hostile mine some distance back from its heading, so as to destroy as long a section as possible of his work and for the reason that the crater of the countermine may be occupied by the attack, and should not therefore be formed near the defenders' position.

A *camouflet* is a countermine so charged as to blow the attacking mine without disturbing the surface he ground. Hence no crater is formed.

Rate of Workings. The following table gives an estimate of the men and tools required for shafts and galleries, with the probable rate of advance in good soil:

RATE OF WORKING.

Kind of gallery, etc.	Men.		Tools.														
	N. C. officers.	Miners.	Picks.	Miner's Picks.	Push Picks.	Shovels.	Miner's shovels.	Miner's truck.	Field levels.	Measuring rod, 6'.	Tracing line.	Mauls or sledges.	Canvas buckets.	Rope ladder.	Wheelbarrows.	Miner's bellows.	Progress, ins. per hour.
Great gallery or blind gallery....	1	*12	4	2	2	8	...	....	1	1	1	1	...	...	4	...	12
Common gallery...	1	4	...	1	1	2	1	1	1	1	1	1	...	...	...	1	12
Half gallery........	1	†4	...	1	1	2	1	1	1	1	1	1	...	...	...	1	16
Branch gallery....	1	†4	...	1	1	2	1	1	1	1	1	1	...	...	...	1	24
Small branch......	1	3	...	1	1	...	2	§1	‡	1	1	1	...	...	...	1	30 to 36
Shaft.............	1	‖4	...	1	1	2	1	....	1	1	1	1	1	1	...	...	18 24

From Engineer Field Manual

* Four of these may be unskilled laborers.

† Number required at commencement of gallery. Beyond 4 ft. add one man, and one man additional for every 20 ft. of gallery.

‡ One mason's level.

§ Instead of a truck a canvas bag may be used. A large hoe or drag may be used to draw back the earth from the face of the gallery.

‖ These numbers are for small shafts of about 2 ft. by 4 ft. Large shafts require a larger force. They advance at about the same rate as galleries of equal cross-section.

CHAPTER XI.

DEMOLITIONS.

An important part of the engineer's work in the field is the demolition of obstacles or hindrances to his own advance, and of things which may prove of material assistance to the enemy. His two principal agents are fire and explosives.

HIGH EXPLOSIVES.

Regarding the latter, there appeared recently in the "Columbia Alumni News," New York, Vol. 7, No. 20, Feb. 18, 1916, page 581, an article on High Explosives by M. C. Whitaker, Professor of Engineering Chemistry. This article had been delivered as an address to the Columbia Alumni, and the material is so applicable to the subject in hand, that, with the permission of Prof. Whitaker, it is here presented entire:

"The popular idea of an explosive is gunpowder. This is a mixture of 75 per cent. saltpeter, 10 per cent. sulphur and 15 per cent. charcoal. These substances are carefully ground together and pressed into a cake. After being carefully dried the cakes are broken into lumps and sized in order to produce the different grades of powder required. The size of the particles has a direct bearing on the rate of combustion, and by the proper selection a suitable explosive is thus found to meet the requirements of the different sized guns, ranging from small rifles to heavy mortars.

Within the span of our lives, however, the manufacture of explosives has undergone a great change. The requirements for explosive powder and accuracy have become more exacting as the range of the guns and the

accuracy of gun fire has increased. We have been tremendously impressed at the reports of the results of the heavy artillery in the European war, but it is doubtful if the layman has given much study or thought to the means by which these results have been accomplished. For our purposes we may arrange explosives into (1) that class of materials which give their explosive force through rapid combustion, e. g., gunpowders, smokeless powders, etc.; (2) the class which derives its explosive force from detonation, e. g., nitroglycerine, guncotton, picric acid and trinitrotoluol; and (3) detonators, or those substances which explode with extreme violence on the application of heat or a shock, such as fulminates.

Combustibles and Detonants.

The combustible explosives are sometimes classed as low explosives and the detonatable materials as high explosives, and, again, the combustible explosives are frequently classed as propellants, while the detonatable substances are classed as disruptive explosives.

In the old style explosives, such as gunpowder, the explosive constituents were mixed together as intimately as possible, while in the new type of powders the constituents required to produce an explosive effect are contained in the molecules of the chemical compound. This change in the make-up of an explosive substance has the effect of increasing the speed with which the explosive action takes place, and fixing with accuracy and definiteness the composition of every particle of the explosive material. Accurate control of the composition of the explosive, uniformity throughout its entire body and the definiteness of its composition are factors which control the dependability, accuracy, safety and all other elements in the modern practice of gun fire.

It is obvious that the pressure exerted by the charge

of exploding powder on the projectile must be uniform for every shot, otherwise it would be impossible to rely upon the propellant to obtain duplicate results. The force of a propellant depends upon its decomposition into gases at greatly elevated temperatures, and the pressure which is exerts upon the breech of the gun and the projectile is dependent both upon the amount of gas produced and the temperature generated by the explosion. It is clear from this that any slight variation in the composition of the powders would result in wide variations of both temperature and pressure. It is interesting to note what these pressures and temperatures actually are:

	Lbs. per sq. in.	Temp.
Gunpowder	30,815	2910°C.
Nitrocellulose powders (U. S. A.)	32,365	2676°C.
Ballistite (nitroglycerine)	34,696	3384°C.

In view of the importance of the composition control, it is apparent that a great step in advance was made when mechanical mixtures such as gunpowder were replaced by explosive chemical compounds, such as nitrocellulose smokeless powders. The explosion of a powder in the breech of a gun for the purpose of throwing the projectile is essentially an action of rapid combustion, and is entirely different from the detonation characteristic of high explosives, such as nitroglycerine. If a propellant should detonate, it would be useless as a propellant and the detonation would doubtless rupture the gun without discharging the projectile. It is extremely important, therefore, in the manufacture of powders, that the element of detonation be entirely eliminated.

The most common form of smokeless powder is made by the treatment of cotton or some pure form of cellulose with a mixture of nitric and sulphuric acid, for the formation of a chemical compound known as nitrocel-

lulose. There are several kinds of nitrocellulose, grading from the lower degrees of nitration to the higher. The lower nitrocellulose compounds are known as soluble nitrocellulose, and form the combustible class of propellant explosives. The higher degrees of nitration give compounds known as guncotton, which are detonatable explosives. This latter class of compounds, however, is not soluble, and this difference gives a clear line of demarkation between those nitrocelluloses which are safe to use as propellant powders and the other class, which are used as detonatable explosives.

How Smokeless Powder Is Made.

The soluble nitrocelluloses are gelatinized by the use of various solvents, such as grain alcohol mixed with ether or with acetone. When the solvent is driven off a hard, bone-like mass is left, which is one of the forms of smokeless powder. The explosive pressure of these nitrocellulose gels may be increased by the addition of other constituents; for example, nitroglycerine is frequently used, especially in the specifications of England and France. Some of the powders now being used in Europe contain as high as 50 per cent. of nitroglycerine. Under ordinary conditions nitroglycerine is a highly detonatable explosive, but when incorporated in the nitrocellulose gel, it is reduced to a condition where it functions as a combustible propellant and is not detonatable.

The nitrocellulose gel is pressed into large cakes which are transferred to a squirting press, similar to that used for squirting macaroni. From this press it is squirted into continuous rods or fibers of any desired shape, cut up into short lengths, carefully dried to remove and recover the last traces of solvent, and then stored, ready for use.

Certain modifications in the formula, changes in the shape and size of the grains and other alterations are

made to meet the various military and sporting requirements. For example, the powder for the sixteen-inch coast defence guns comes in the form of pieces approximately five-eighths inch in diameter and two inches long, while a sample of the sporting powder is illustrated by fine grains the size of a mustard seed.

Stability is an important consideration in the manufacture of smokeless powder, and certain means have been developed which render them more stable and less liable to change or deterioration. One of the most important chemicals, used almost universally for this purpose, is di-phenyl-amine, and all smokeless powders contain approximately 1 per cent. of this chemical. Prior to August, 1914, practically all of the di-phenyl-amine used by all of the nations of the world was made in Germany and marketed through an English agency. Since the German supply has been cut off, the manufacture of this product has been developed in this country, and we are now able to supply our own needs.

High explosives, as a class, include all of those compounds and mixtures which are detonatable. They are used both in engineering practice and for military purposes as disruptive agents. In engineering work, the most common form of disruptive agent is dynamite, which is a mixture of nitroglycerine with some form of inert or active absorbent or carrier commonly known in the dynamite industry as "dope." The older forms of dynamite were made by soaking up the liquid nitroglycerine in infusorial earth, sawdust, wood fiber or some such absorptive material. In the more powerful dynamites the filler is also an explosive substance, such as cotton, ammonium nitrate and similar materials. Nitroglycerine, the basic explosive substance of dynamite, is made by the action of a mixture of sulphuric and nitric acid on glycerine. Glycerine, as you will recall, is a by-product of the soap industry and results from the treatment of a fat such as cottonseed oil, corn

oil, tallow, etc., with an alkali to form a soap and crude glycerine. The glycerine recovered from this operation is carefully refined and purified for the purpose of making nitroglycerine. One of the commercial grades is known as dynamite glycerine. Liquid nitroglycerine is an extremely dangerous explosive. Its danger lies in the fact that it is easily detonated and explodes with great violence. Its incorporation with some filler, after the inventions of Nobel, so that it may be treated and handled as a solid, minimized to a great degree the explosive danger. Dynamite could not, however, be used in any operations such as the filling of a shell, where it would be subjected to the severe shock of firing, without great danger of its detonating. As a consequence, it is not possible to use dynamite as a high explosive charge in artillery shells, whereas in engineering work it is a perfectly satisfactory and safe disruptive explosive.

Guncotton, that is to say, the higher degrees of nitration of ordinary cellulose, is also an easily detonatable explosive and cannot be used in any operations where it would be subjected to severe shock.

Nitroglycerine and guncotton are used in certain classes of war work, for bombs, charging of torpedoes, etc., where they are not subjected to rough handling or to the shock of being discharged from a gun.

Picric Acid.

High explosives for the charging of shells must necessarily be selected from substances which are detonatable by the use of a proper detonator, yet at the same time will not be detonated when subjected to the ordinary methods of military handling, and to the shock of being discharged from the gun. Detonatable explosives to meet those conditions are of comparatively recent origin. The oldest compound applied for this purpose is picric acid. The use of this substance

for loading shells was first suggested in 1886 by Turpin, in France. The compound itself has been well known for many years not as an explosive, but as one of the simplest forms of a yellow dyestuff. As a result of Turpin's investigations, picric acid has since been adopted in England under the name of Lyddite, in France under the name of Melinite, and the Japanese used the compound effectively in the Russo-Japanese war under the name of Shimose.

Picric acid is made by the treatment of phenol or carbolic acid with a mixture of sulphuric and nitric acid. The product, a yellow crystalline powder, is carefully purified and used either alone or with other explosive compounds for shell charges. It is melted and poured into the shells, leaving suitable space for the detonating cap. It is very stable to shock and the most powerful of the shell explosives of this class. It has some objectionable characteristics in that it is an acid and has a tendency to form salts which are unstable. Several fatal accidents have been traced to the formation of calcium and lead salts, which are especially sensitive. Notwithstanding these objections, however, picric acid has proved to be one of the most important and generally used explosives in the present war, and it is being manufactured both in this country and abroad in enormous quantities.

The phenol, or carbolic acid, from which picric acid is made is obtained under ordinary conditions from the distillation of coal-tar. The enormous demand for picric acid under war conditions has created a corresponding demand for phenol, and the price has advanced from 19 cents to $1.50 per pound. Phenol can be made and has been made for a number of years in Germany, synthetically, from benzol, another common constituent of coal-tar. In the manufacture of phenol the benzol is treated successively with sulphuric acid, lime, soda ash, caustic potash or soda, with the final

production of crude phenol. This crude phenol is carefully distilled in a vacuum and produces the chemically pure product, sample of which is shown. A large number of synthetic phenol plants have been started in the United States since the outbreak of the war in Europe, and chemical engineers have devoted a great deal of attention to the development of this industry in America.

T. N. T.

Another interesting high explosive for shells, and the one which is said to have been so effective in the reduction of the forts at Liege, is tri-nitro-toluol, commonly known as T.N.T. This product is made by the nitration with a mixture of sulphuric and nitric acid, of toluol, another liquid constituent of coal-tar. The increased demand for toluol has run the price from 40 cents a gallon before the war to as high as $5 or $6 a gallon. Numerous processes have been more or less successfully developed for the manufacture of toluol. One of the most important of these is our own Rittman process, which is in successful operation in Pittsburgh, manufacturing a mixture of toluol and benzol.

T.N.T. is a light yellowish solid, very stable to shocks and abrasions, and is in every way an ideal disruptive explosive, although not quite so powerful as picric acid. It is non-acid and does not form unstable compounds. It is practically impossible to explode a charge of T. N. T. except by the use of powerful detonators.

Detonators are a class of compounds which explode with extreme violence and sharpness. On account of their sharp explosive wave, they have the power of setting up a corresponding explosive wave in a large number of otherwise more or less stable substances, such as trinitrotoluol and picric acid, and with fair ease such substances as nitroglycerine and gun-cotton. The class of compounds known as metallic fulminates

are commonly used as detonators. The most important of these is the fulminate of mercury. This product is made by the action of nitric acid and alcohol on mercury. It is a grayish white crystalline powder and is stored for safety in small bags suspended in a tank of water. It detonates by shock, as, for example, by the firing pin of a gun, or by heat of approximately 200 deg. C., as by a fuse. Small charges of these detonators are imbedded in the main explosive charge, and the sharp shock of their explosion detonates the entire mass. It should also be noted that by the use of these detonators it is possible to explode the shell either by a time fuse or by impact, and both methods are used according to the character of the operation.

How to Stop the War.

You have doubtless noticed that the same chemicals are used in some phase or other, in each one of the processes of manufacturing high explosives, and smokeless powders. I refer particularly to the use of sulphuric acid and nitric acid. Sulphuric acid is doubtless the most important of these, because it is essential not only in making all explosives, but in the manufacture of nitric acid itself. Sulphuric acid may be said, therefore, to be the basic chemical on which the entire war is dependent, and there is nothing which would more effectively stop a war than to stop the production of sulphuric acid. The raw materials for making sulphuric acid are, (1) sulphur, or (2) pyrites, or (3) sulphur gases from smelting operations. The sulphur used in America comes from the deposits in Louisiana and Texas, where it literally flows from the earth at the rate of 500 to 1000 tons per day by the famous Frasch process. The pyrites, while produced to a small extent in this country, comes largely from Spain or Portugal. The smelter gases are necessarily available only at the points where the smelting opera-

tions are carried out. It is obvious that we would be seriously handicapped in case the Spanish pyrites supply was cut off, and it is even more serious to note that the sulphur deposits of Louisiana and Texas are both near the coast and are undefended. The loss of control of these two principal raw materials for sulphuric acid manufacture would literally put a stop to ammunition production in this country.

Chemical Preparedness.

Another fundamental raw material of the explosive industry is nitric acid, which is obtained from nitrate of soda, the sole source of supply of which, for this country, is Chili. No progress has been made, and very little if any interest has been shown in the development of an independent self-contained source of supply for nitrates or nitric acid in America. It is clearly apparent that a few fast cruisers could cut off our supply of nitrate, and the stock available in this country would not enable us to carry on a defensive war more than two or three months. One might naturally ask, what is being done to safeguard this country against such a contingency, and the answer is, nothing.

The previous speaker referred to certain influences which appear in diplcmatic dealings, but it is my belief that one of the most potent influences in a successful diplomacy is to be found in the adequate and intelligent solution of some of the problems presented in connection with the industries now under discussion. One of our statesmen has declared that an army of a million men might be provided in a few days, but what earthly good would a million men be if they are not provided with the modern facilities and machinery for conducting a defense. The most apparent lesson to be drawn from the conditions in Europe is that there is a great deal in an army besides men. The fact that the power of defence in the United States could be

rendered ineffective in two or three months by a few warships stopping the supply of nitrate from Chili, taking possession of the sulphur deposits of Louisiana and Texas, and crippling other important industrial centers, is well known in every capital in Europe, and such knowledge does not tend to add force nor emphasis to our diplomatic notes.

Germany has clearly indicated the solution of the nitrate problem. She has been cut off from the nitrate supply of Chili and from the pyrites supply from Spain for months, but long before that condition developed, she had worked out and put into operation within her own borders processes for manufacturing nitric acid synthetically. This result is accomplished in Germany by three important industrial processes which have been developed within the last ten or fifteen years: (1) The process for the direct oxidation of the nitrogen of the air, (2) the process of oxidizing ammonia made by the Haber method of combining nitrogen and hydrogen, in the presence of catalytic agents, and (3) another process oxidizing ammonia made by the syanamid process, in which the nitrogen of the air is fixed in calcium carbide, and later converted into ammonia. The power of Germany would have been broken months ago, had it not been for the foresight and the skill required to provide an independent supply of the fundamental chemicals required in explosive manufacture."

APPLICATIONS.

Military Explosives.

Of these explosives, *black powder* will seldom be available and therefore will be little used.

Gun-cotton is powerful and efficient, but will not be available unless carried along. Dry gun-cotton is very sensitive, and therefore dangerous to transport, so that

in carrying this explosive an additional weight of 20 to 25 per cent. of water must be carried, this being about the degree of saturation required to make it safe. A small quantity of dry gun-cotton must also be carried, as this is the only satisfactory primer for the wet material. The dry charge is fired by the ordinary fulminate primer.

Rack-a-rock has the advantage of perfect safety in transportation, being composed of two substances, neither of which is explosive. Powdered chlorate of potash is put up in cloth bags the size of a dynamite cartridge. These are soaked in mono-nitrobenzol, allowed to drain for a minute, and then may be primed and fired similarly to dynamite. This explosive, also, must be carried to be available in the field.

Trinitro-toluol is perfectly safe for any character of transportation, being inert to physical shock, and is detonated only by a powerful fulminate cap. It comes in three forms, the natural granular substance in paper cartridges, the TNT blocks into which it is pressed for the U. S. Engineers, and *trotol gelatine,* the preparation of Capt. Woodward of the 22nd Corps of Engineers. This substance is very powerful, quick detonating and shattering. It has not the noxious fumes of dynamite, will not freeze, and is insensitive to shock. Its great disadvantage lies in the fact that, like gun-cotton and rack-a-rock, it must be carried to be available when desired.

The well-known *dynamite,* reliable when handled carefully, available at any country store, and familiar to nearly every engineer and foreman, will probably form the bulk of the explosive used by the army in the field.

Firing Charges.

These explosives, with the exception of black powder, are of the detonating variety, and may be exploded by

means of the fulminate cap, either by fuse or by electricity. The former is of two varieties, *Bickford,* which is *white,* has a *twisted* surface, and burns at the rate of *two* feet per minute, and the *Instantaneous* fuse, which is *red,* has a rather smooth, *woven* surface, and burns at the rate of about 120 feet per *second.* Electric ignition is preferable, as the time of firing is under the control of the operator and a number of charges may be fired simultaneously. When it is required to fire several charges simultaneously by fuse, a length of instantaneous fuse should be connected to the primer of each charge, and the various free ends gathered into a small bag of powder. This is ignited by a piece of Bickford fuse, cut long enough to allow the escape of the powder man.

Demolition by Explosives.

The most important demolitions affect lines of communication, and must not be undertaken except as a matter of military necessity and under positive written orders from the commander of the field forces. Large bridges are attacked in the chords, near the abutments where the chord sections are smallest. All longitudinal members should be cut. Arches are cut at the crown if single, or if double, at the pier between them. Trees not over a foot in diameter may be felled by firing a charge in the shape of a chain of dynamite cartridges encircling their trunks. Twenty per cent. of this amount will have the same effect if placed in a hole bored in the trunk. Used in this latter way, one stick of 40 per cent. dynamite will cut about one square foot of timber.

Railroad track is best destroyed by *mud-capping* four charges of about one stick each against the rail webs, so as to cut each rail in two places. The section of track is then turned over, the ties pried off and

a bonfire made of them. The rails are heated in the fire and *twisted,* using pincers, crowbars through the splice-bolt holes, or any manner of gripping the rail firmly. Rails thus twisted cannot be used again until re-rolled, whereas if they are simply bent around a tree, they may be roughly straightened in the field. If it be desired to destroy the track without permanent damage to the material, the fish-plates may be taken off at the ends of a long section, the loosened portion lifted by a large force of men and rolled down the embankment. It must be remembered that unless the demolition be most thorough, good railway troops can repair track about as rapidly as it can be destroyed.

Small bridges, intended to be demolished as soon as the immediate need for them has passed, are usually prepared for demolition during construction, so that the charges may be fired when the last troops have crossed, and before a closely pursuing enemy can follow.

Fig. 41 shows the placing of a charge of rack-à-rock

FIG 41. PLACING CHARGE

in a spar bridge, Fig. 42 the explosion, and Fig. 43 the destroyed bridge.

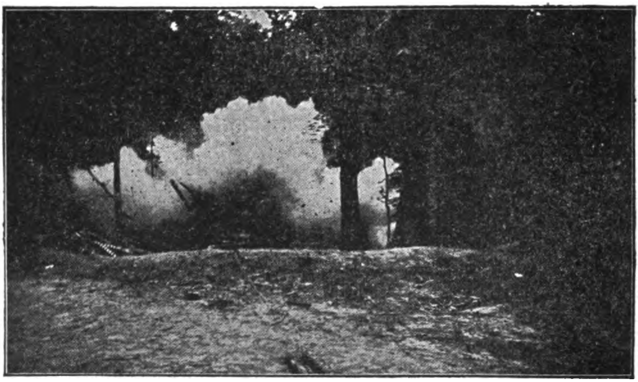


FIG. 42. THE EXPLOSION

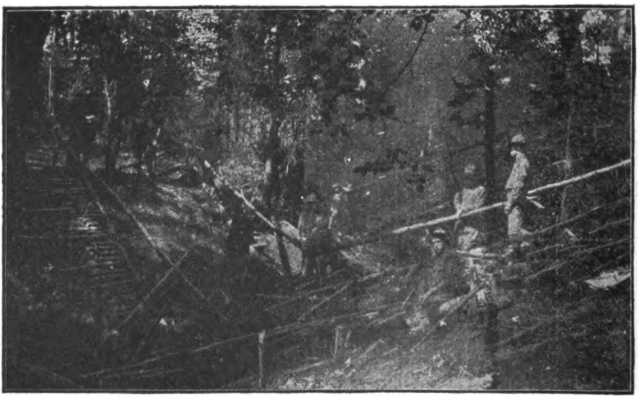


FIG. 43. BRIDGE DESTROYED

For the destruction of woods, villages, etc., which must be razed to give a clear field of fire, explosives will not be wasted unless great haste is required. Free use of the axe, and the assistance of troops from the infantry, will accomplish much in a short time. If the smoke is not objectionable as betraying the position, this work may be done largely by means of fire.

XII.

MILITARY BRIDGES.

Military bridges are of many types. From the felled log that may enable a single messenger to cross with an important order, to the railway trestle that carries the supply trains, all sorts and sizes of bridges find their application to military purposes. Outside of certain improvised types, however, and others that are little used, military bridges may be grouped in four general classes: truss, pile, spar and floating. *Truss bridges* find their principal application along the line of communications and will be little used at the front.

Loads.

The loads which military bridges will have to support are about as follows, in pounds per *linear* foot of bridge:

Infantry,	single file, heavy marching order	140	pounds
"	double file, " " "	280	"
"	col. of fours " " "	560	"
Cavalry,	single file	196	"
"	double file	392	"
"	column of fours	784	"

WEIGHTS OF GUNS AND MILITARY CARRIAGES, FULLY LOADED FOR TRAVELING. *

	Weight on the Wheels. Front Lbs.	Hind Lbs.	Distance between Axles, c. to c. Ft.	Ins.	Width of wheel Track, c. to c Ft.
3.2-in. B. L. F. gun	1,735	2,070	8	7	5
3.6-in. B. L. F. gun	1,870	2,415	8	9	5
3.2-in. caisson	1,775	2,805	8	5¾	5
3.6-in. caisson	1,930	3,070	8	6	5
Battery and forge wagon	1,130	2,130	8	6	5
5-in. siege rifle	2,530	6,425	8	1¼	5
7-in. siege howitzer	2,510	6,920	8	1¼	5
Maxim automatic	1,950	1,230	7	0	5
Gatling	754	1,075	7	0	5
Army escort wagon (4 mules)	2,500	2,500	5	9½	5
Army wagon (6 mules)	3,500	3,500	6	1½	5

*From Engineer Field Manual.

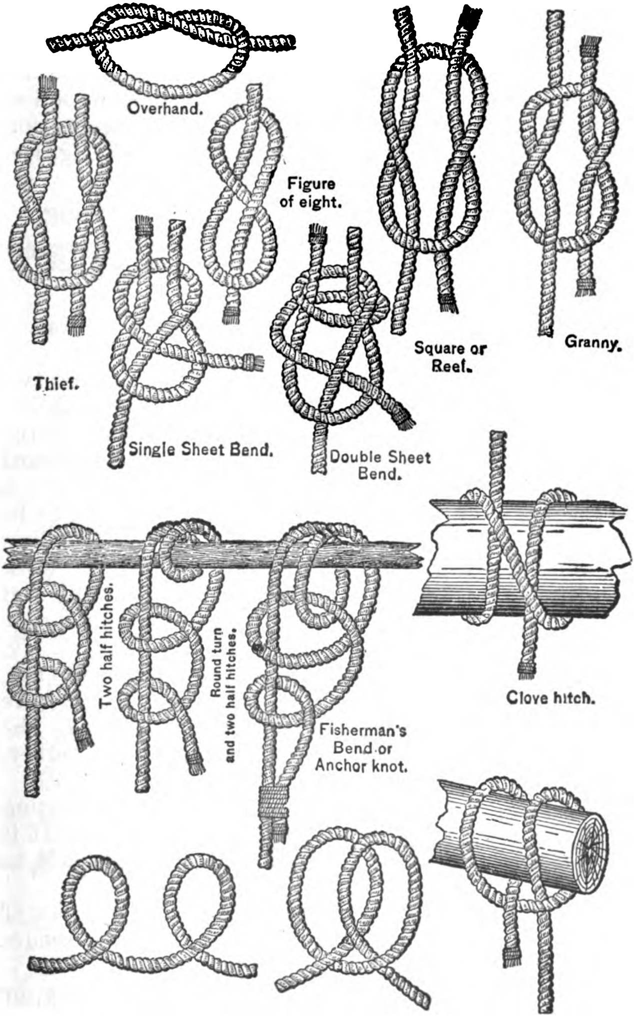

Overhand.
Figure of eight.
Square or Reef.
Granny.
Thief.
Single Sheet Bend.
Double Sheet Bend.
Two half hitches.
Round turn and two half hitches.
Fisherman's Bend or Anchor knot.
Clove hitch.

FIG. 44. KNOTS

Knots and Lashings.

A knowledge of a number of the common knots, splices and lashings is essential to the construction of military bridges, particularly those of the spar type. Those described herein are taken from the Engineer Field Manual:

The following knots are most useful in bridging.

Overhand knot, used at the end of a rope to prevent unreeving or to prevent the end of the rope from slipping through a block.

Figure-of-eight knot, used for purposes similar to above.

Square or *reef knot,* commonly used for joining two ropes of the same size. The standing and running parts of each rope must pass through the loop of the other in the same direction, i. e., from above downward or vice versa; otherwise a *granny* is made, which is a useless knot that will not hold. The reef knot can be upset by taking one end of the rope and its standing part and pulling them in opposite directions. With dry rope a reef knot is as strong as the rope; with wet rope it slips before the rope breaks, while a double sheet bend is found to hold.

The *thief knot,* commonly mistaken for a reef knot, should be avoided as it will not hold. The figure shows that the end of each rope turns around the standing part instead of around the end of the other, as in a reef knot.

Single sheet bend, weaver's knot, used for joining ropes together, especially when unequal in size. It is more secure than the reef knot but more difficult to untie.

Double sheet bend, used also for fastening ropes of unequal sizes, especially wet ones, and is more secure than the single sheet bend.

Two half hitches, especially useful for belaying, or

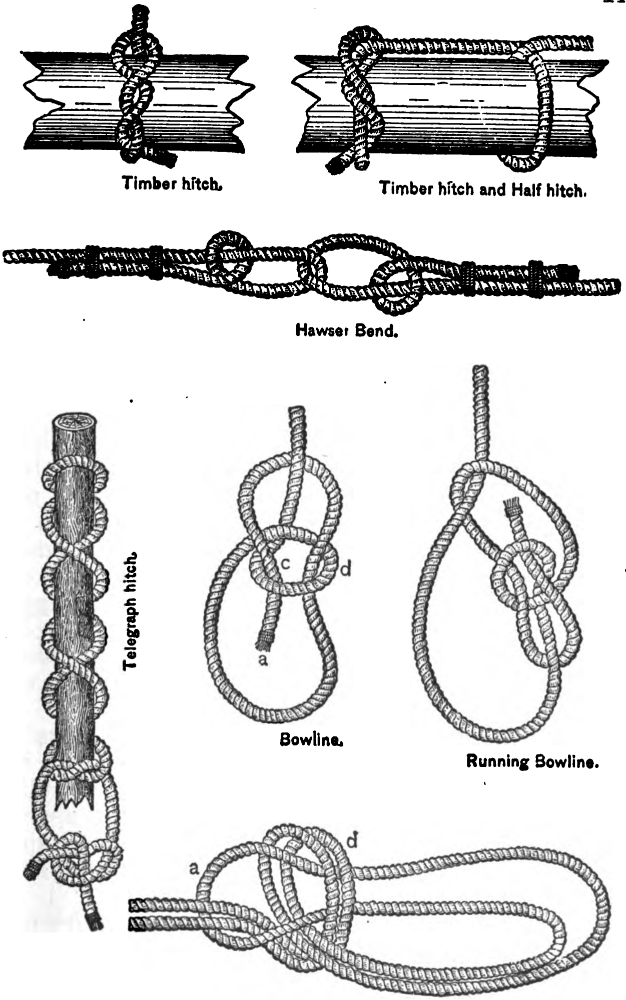

Timber hitch.
Timber hitch and Half hitch.
Hawser Bend.
Telegraph hitch.
c
d
a
Bowline.
Running Bowline.
a
d

FIG. 45. KNOTS

making fast the end of a rope round its own standing part. The end may be lashed down or seized to the standing part with a piece of spun yarn; this adds to its security and prevents slipping.

This knot should never be used for hoisting a spar.

Round turn and *two half hitches,* like the preceding except that a turn is first taken round the spar or post.

Fisherman's bend or *anchor knot,* used for fastening a rope to a ring or anchor. Take two turns round the iron, then a half hitch round the standing part and between the rings and the turns, lastly a half hitch round the standing part.

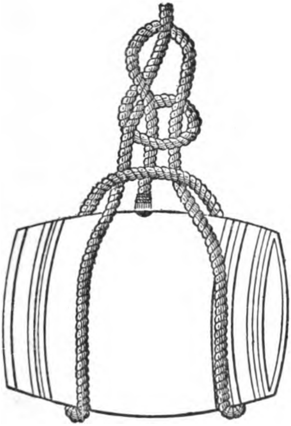
Clove hitch, generally used for fastening a rope at right angles to a spar or at the commencement of a lashing. If the end of the spar is free, the hitch is made by first forming two loops, placing the right-hand loop over the other one and slipping the double loop over the end of the spar. If this can not be done, pass the end of the rope round the spar, bring it up to the right of the standing part, cross over the latter, make another turn round the spar, and bring up the end between the spar, the last turn, and the standing part. When used for securing guys to sheer legs, etc., the knot should be made with a long end, which is formed into two half hitches round the standing part and secured to it with spun yarn.

Timber hitch, used for hauling and lifting spars. It can easily be loosed when the strain is taken off, but will not slip under a pull. When used for hauling spars, a half hitch is added near the end of the spar.

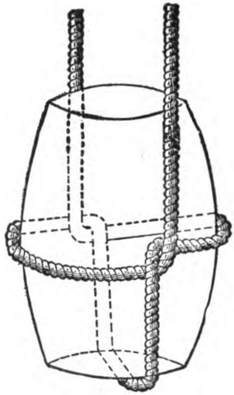
Telegraph hitch, used for hoisting or hauling a spar.

Hawser bend, used for joining two large cables. Each end is seized to its own standing part.

Bowline forms a loop that will not slip. Make loop with the standing part of the rope underneath, pass the end from below through the loop, over the part round the standing part of the rope, and then down



Sling for barrel horizontal.



Sling for barrel vertical.

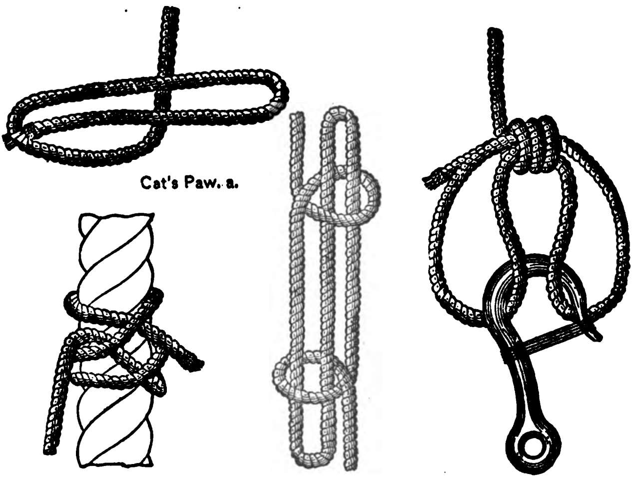


FIG. 46. KNOTS

through the loop *c*. The length of bight depends upon the purpose for which the knot is required.

Bowline on a bight. The first part is made like the above, with the double part of a rope; then the bight *a* is pulled through sufficiently to allow it to be bent past *d* and come up in the position shown. It makes a more comfortable sling for a man than a single bight.

Running bowline. A slip noose formed by a bowline running on the standing part of the line.

Barrel Sling. To sling a barrel or box horizontally, make a bowline with a long bight and apply it as shown.

To sling a barrel vertically, make an overhand knot on top of the two parts of the rope; open out the knot and slip each half of it down the sides of the cask; secure with a bowline.

Cat's-paw. Form two equal bights. Take one in each hand and roll them along the standing part till surrounded by three turns of the standing part; then bring both loops (or bights) together and pass over the hook of a block.

Sheep shank, used for shortening a rope or to pass by a weak spot; a half hitch is taken with the standing parts around the bights.

Rolling hitch, used for hauling a large rope or cable. Two turns are taken round the large rope in the direction in which it is to be hauled, and one half hitch on the other side of the hauling part. A useful knot and quickly made.

For armored cable, or wet manila rope, the hitch must be made with a strap of rope yarn. Rope will not hold.

Blackwall hitch, used for attaching a single rope to a hook of a block for hoisting.

Mooring knot. Take two turns round the mooring or snubbing post, pass the free end of the rope under the

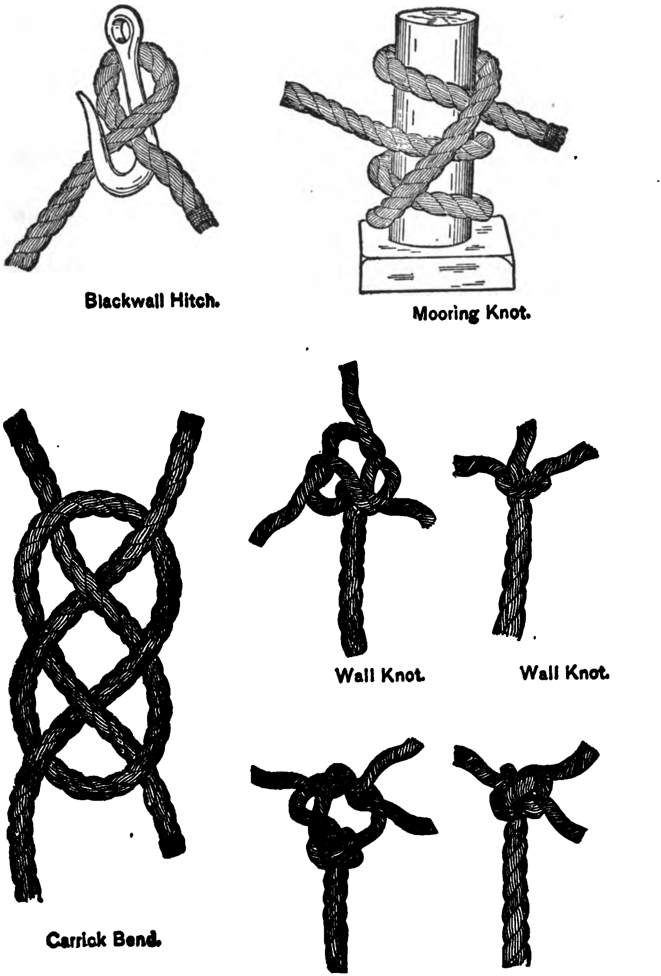

Blackwall Hitch.
Mooring Knot.
Wall Knot.
Wall Knot.
Carrick Bend.

FIG. 47. KNOTS

standing part; take a third turn above the other and pass the free end between the two upper turns.

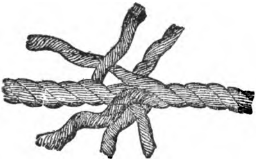
Carrick bend, much used for hawsers and to fasten guys to derricks.

Wall knot, and

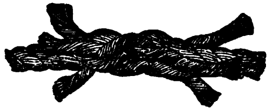
Crown on wall, both used for finishing off the ends of ropes to prevent unstranding.

To make a *short splice,* unlay the strands of each rope for a convenient length. Bring the rope ends together so that each strand of one rope lies between the two consecutive strands of the other rope. Draw the strands of the first rope along the second and grasp with one hand. Then work a free strand of the second rope over the nearest strand of the first rope and under the second strand, working in a direction opposite to the twist of the rope. The same operation applied to all the strands will give the result shown in Fig. 48. The splicing may be continued in the same manner to any extent and the free ends of the strands may be cut off when desired. The splice may be neatly tapered by cutting out a few fibers from each strand each time it is passed through the rope. Rolling under a board or the foot will make the splice compact.

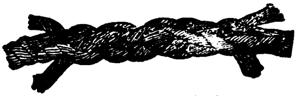
Long splice. Unlay the strands of each rope for a convenient length and bring together as for a short splice. Unlay to any desired length a strand, *d,* of one rope, laying in its place the nearest strand, *a,* of the other rope. Repeat the operation in the opposite direction with two other strands, *c* and *f*. Strands *b* and *e* are shown secured by unlaying half of each for a suitable length and laying half of the other in place of the unlayed portions, the loose ends being passed through the rope. This splice is used when the rope is to run through a block. The diameter of the rope is not enlarged at the splice. The ends of the strands should not be trimmed off close until the splice has been thoroughly stretched by work.



Short Splice.



Short Splice



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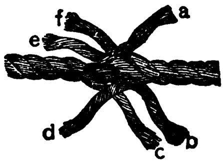
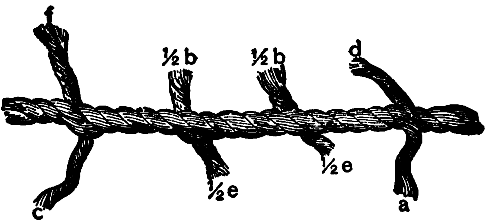


Long Splice.



Long Splice.

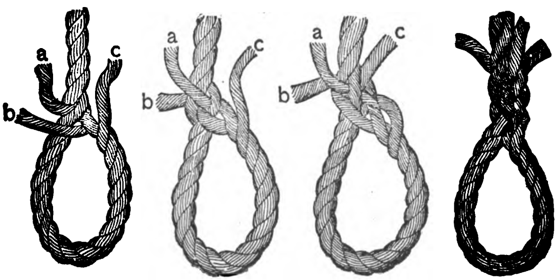


FIG. 48. SPLICES

Eye splice. Unlay a convenient length of rope. Pass one loose strand, *a,* under one strand of the rope, forming an eye of the proper size. Pass a second loose strand of the rope next to the strand which secures *a.* Pass the third strand, *c,* under the strand next to that which secures *b.* Draw all taut and continue and complete as for a short splice.

To *lash a transom to an upright spar,* transom in front of upright, a clove hitch is made round the upright a few inches below the transom. The lashing is brought under the transom, up in front of it, horizontally behind the upright, down in front of the transom and above the clove hitch. The following turns are kept outside the previous ones on one spar and inside on the other, not riding over the turns already made. Four turns or more are required. A couple of frapping turns are then taken between the spars, around the lashing, and the lashing is finished off either round one of the spars or any part of the lashing through which the rope can be passed. The final clove hitch should never be made around the spar on the side toward which the stress is to come, as it may jam and be difficult to remove. The lashing must be well beaten with handspike or pick handle to tighten it up. This is called a square lashing.

Lashing for a pair of shears. The two spars for the shears are laid alongside of each other with their butts on the ground, the points below where the lashing is to be resting on a skid. A clove hitch is made round one spar and the lashing taken loosely eight or nine times about the two spars above it without riding. A couple of frapping turns are then taken between the spars and the lashing is finished off with a clove hitch above the turns on one of the spars. The butts of the spars are then opened out and a sling passed over the fork, to which the block is hooked or lashed, and fore and back guys are made fast with clove hitches to the bot-

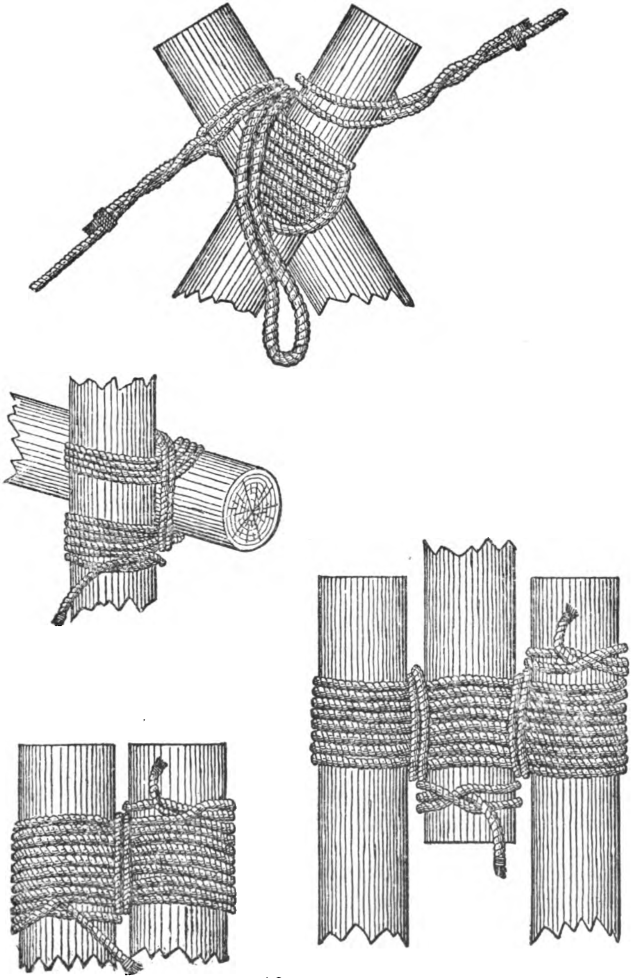


FIG. 49. LASHINGS

tom and top spars, respectively, just above the fork. (Top of Fig. 49).

To lash three spars together as for a gin or tripod. Mark on each spar the distance from the butt to the center of the lashing. Lay two of the spars parallel to each other with an interval a little greater than the diameter. Rest their tips on a skid and lay the third spar between them with its butt in the opposite direction so that the marks on the three spars will be in line. Make a clove hitch on one of the outer spars below the lashing and take eight or nine loose turns around the three. Take a couple of frapping turns between each pair of spars in succession and finish with a clove hitch on the central spar above the lashing. Pass a sling over the lashing and the tripod is ready for raising.

To prepare a fastening in the ground for the attachment of guys or purchases, stout pickets are driven into the ground one behind the other, in the line of pull. The head of each picket except the last is secured by a lashing to the foot of the picket next behind. The lashings are tightened by rack sticks, the points of which are driven into the ground to hold them in position. The distance between the stakes should be several times the height of the stake above the ground.

Another form requiring more labor but having much greater strength is called a *deadman,* and consists of a log laid in a transverse trench with an inclined trench intersecting it at its middle point. The cable is passed down the inclined trench, takes several round turns on the log, and is fastened to it by half hitches and marlin stopping. If the cable is to lead horizontally or inclined downward, it should pass over a log at the outlet of the inclined trench. If the cable is to lead upward this log is not necessary, but the anchor log must be buried ·per.

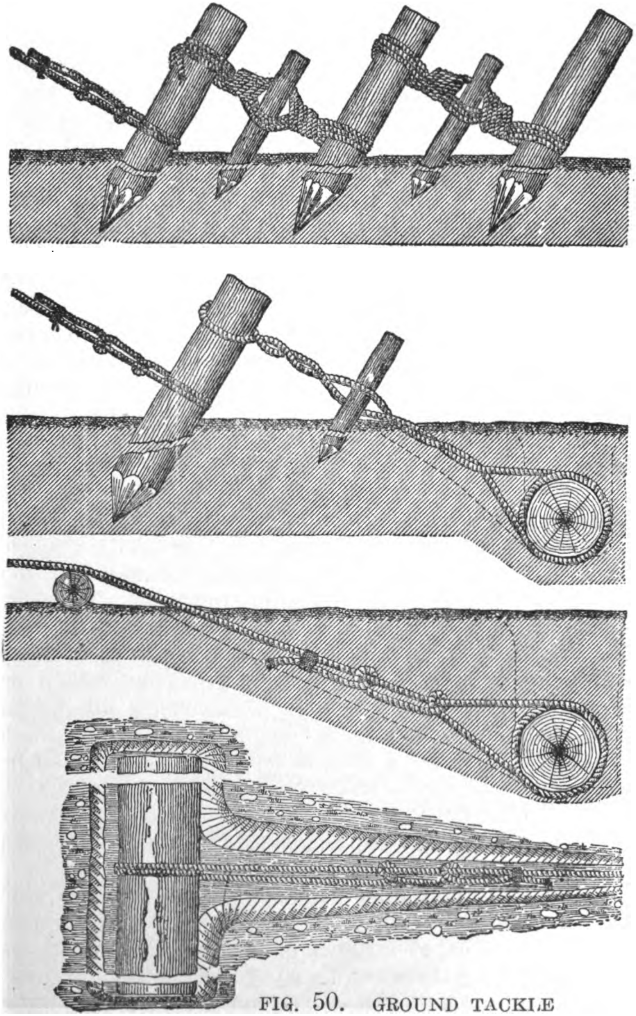


FIG. 50. GROUND TACKLE

Improvised Bridges.

Suspension bridges are sometimes built, but are not generally satisfactory as a field type, owing to their lack of stiffness. With the labor necessary to properly construct such a bridge, with an adequate stiffening truss, a more serviceable truss or pile bridge might be built. However, where the material at hand and the locality are particularly suited to a suspension bridge, there should be no hesitancy in undertaking its construction. The towers may be lashed spar bents, the anchorages *deadmen,* the cable steel wire rope, the suspenders of wire, and the floor system of round timber or ponton material. If a stiffening truss is used, it will probably be of the Howe or Pratt type of bracing, with timber struts and twisted wire diagonals.

An excellent foot suspension bridge may be made from Page woven wire fencing, three lengths being used, one for the bottom and one for each side. The sides may be wrapped around convenient trees or well braced vertical posts and firmly fastened with staples. The bottom is fastened in a similar manner to a log which is staked back of the supporting trees. The floor beams are round or square timbers resting on the bottom wires of the sides and the outer wires of the bottom section of fencing. Floor boards may be nailed or lashed longitudinally to the floor beams, or placed transversely upon stringers resting on the beams. Such a bridge is good for a span of 150 or more feet, can be constructed in an hour if the materials are at hand, and will bear fully equipped infantrymen at intervals of four or five feet. The sag should be about one-tenth of the span.

When only a number of short boards are available for a bridge, as for instance those obtained from packing cases, a sort of latticed girder truss is sometimes built by nailing them together to form chords and diagonals. Similar material is also made into a bowstring

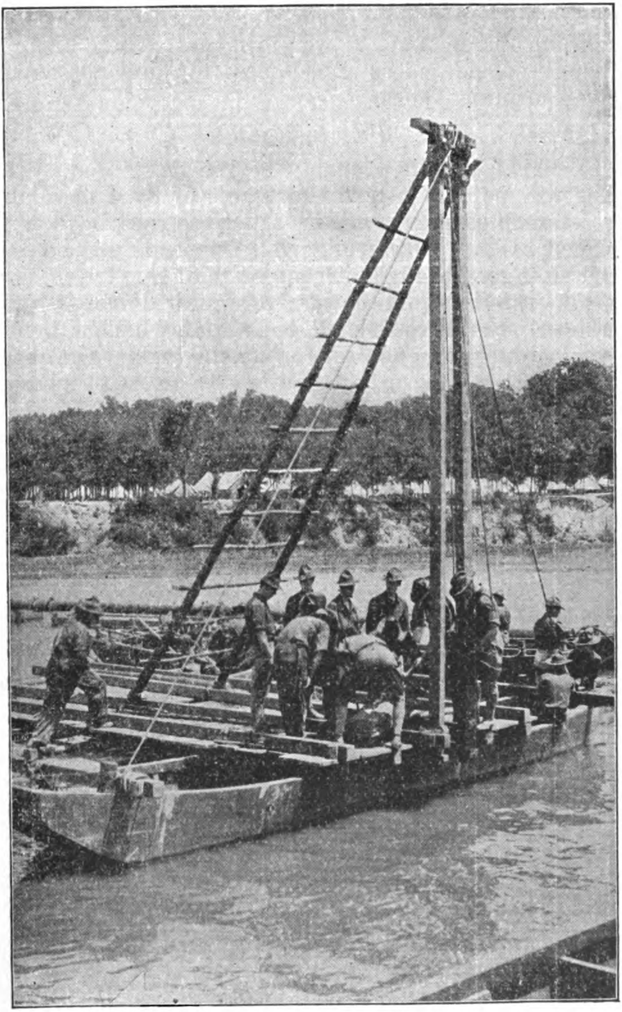


FIG. 51. FLOATING PILE-DRIVER

truss, the chords being formed of boards set on edge, inclosing the ends of the web members. These bridges must be considered as expedients only and not as accepted military types.

Pile Bridges.

Pile bridges will probably be the most used. The piles will be driven by hand mauls or by a field pile driver such as shown in Fig. 51. Here the platform is formed of the ponton material, the leads are ponton floor stringers, the hammer a section of tree trunk, and it is operated by man power. A similar driver is built to rest upon the completed portion of a bridge, cantilevering out to the bent under construction. The outer

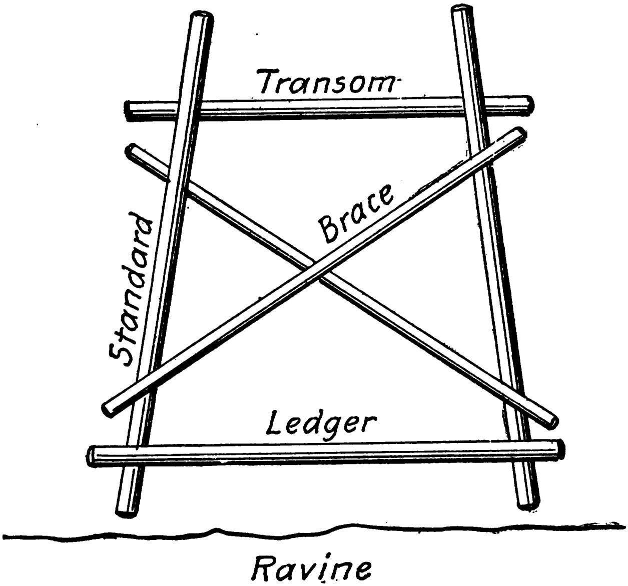


FIG. 52. TRESTLE FOR SPAR BRIDGE

end is trussed up by twisted ropes, passing from the bottom of the leads, over king posts, and down to the rear end of the driver, which is counterweighted by logs or sand bags. The floor of the completed bridge is of plank if available, or caps, stringers, floor and guard timbers may all be of round stuff, laid *corduroy* style.

Spar Bridges.

Spar bridges are in a distinct class by themselves. They have been developed solely by military engineers, and their great advantage lies in the fact that they may be constructed entirely of rough timber, cut at the site, and put together by means of rope lashings. A stream or ravine with steep banks and of no great width is particularly suited for a spar bridge.

Single lock bridge. A trestle as shown in Fig. 52 is built upon each bank, the top of one being made of a

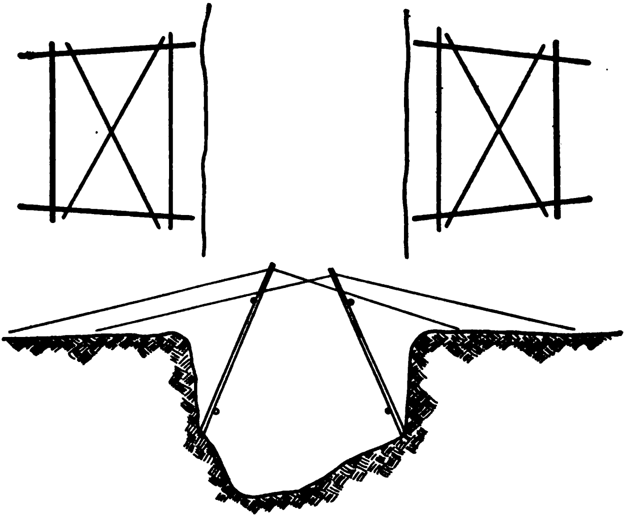


FIG. 53. ERECTION OF SPAR BRIDGE

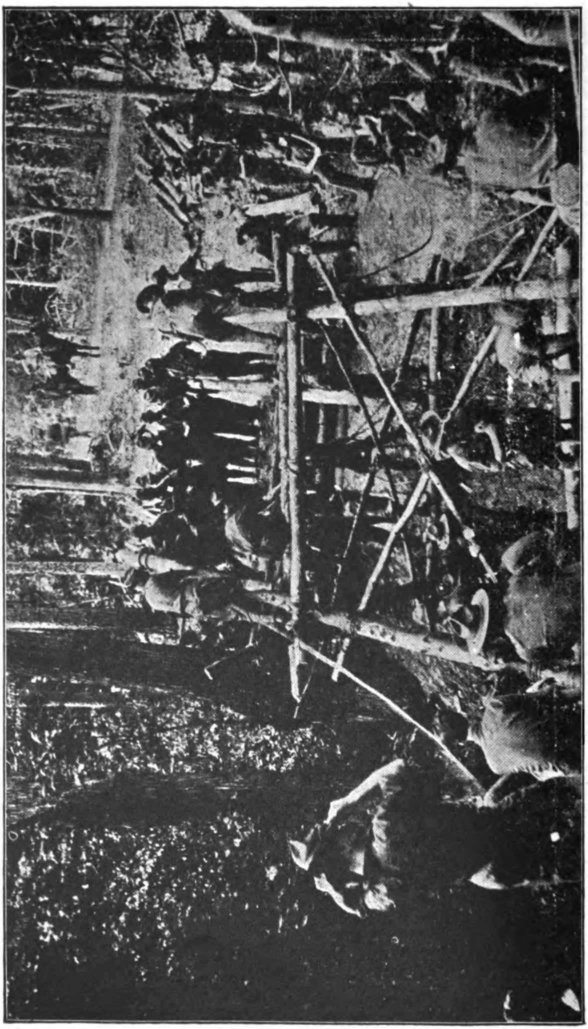
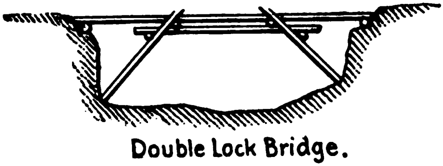


FIG. 54. SINGLE LOCK BRIDGE TRESTLES LOCKED

width to pass readily between the standards of the other. (Fig. 53.) The two are then lowered into the ravine and their transoms locked. (Fig. 54.) A ***road-bearer*** is placed in the fork of the standards, and forms a support in the middle of the span. In a *double lock* bridge (Fig. 55) the trestles do not interlock, but are held apart by two road bearers, lashed to two



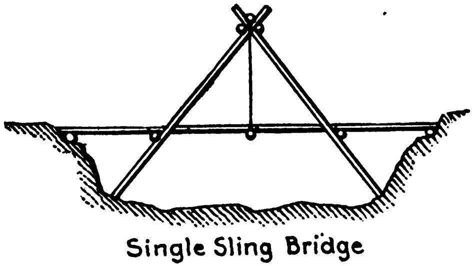


FIG. 55. DOUBLE LOCK AND SINGLE SLING BRIDGES

stringers which rest upon the transoms of the trestles. The bridge thus has *two* supports and *three* panels.

Single Sling Bridge. If the standards of a double lock bridge are extended to a junction above the center of the bridge (Fig. 55), an additional road bearer or floor beam may be suspended from the intersection, and the number of panels increased to *four*. *Double sling* and *triple sling* bridges have been constructed, but the single sling is practically the limit of development of the spar bridge. A sling bridge requires much heavier standards than the double-lock type. Fig. 56 shows a double lock spar bridge.

FIG. 56. DOUBLE LOCK BRIDGE COMPLETED

ROUND TIMBER REQUIRED FOR SPAR BRIDGES.

Kind of bridge.	Spars.	Length.	Diameter. At tip.	Diameter. Throughout or mean.	Purpose.
	No.	Ft.	Ins.	Ins.	
Single lock, 30-ft. span.	4	22	7	.	Standards.
	2	15	.	6	Transoms.
	4	15	.	4 to 6	Ledgers and shore trans.
	4	20	.	3	Diag. braces.
	1	15	.	10	Fork trans.
	10	20	.	6	Balk.
	4	20	.	3 to 6	Side rails.
Double lock, 45-ft. span	4	20	7	.	Standards.
	2	15	.	6	Main trans.
	4	15	.	4 to 6	Ledgers and shore trans.
	2	25	.	8	Distance pcs.
	2	15	.	10	Road trans.
	4	20	.	3	Braces.
	15	20	.	6	Balk.
	4	20	.	4 to 6	Side rails.

From Engineer Field Manual.

ROPE REQUIRED FOR SPAR BRIDGES.

Description and size of ropes.	Single lock. Ropes.	Single lock. Total length.	Single lock. Max. wt.	Double lock. Ropes.	Double lock. Total length.	Double lock. Max. wt.
	No.	Ft.	Lbs.	No.	Ft.	Lbs.
Foot ropes, 3 in. circ., 40 to 60 ft.	4	240	71	4	240	71
Guys, 3 in. circ., 120 to 150 ft.	8	1,200	356	8	1,200	356
2 in. circ., 108 ft.	2	216	29	2	216	29
1½ in. circ., 54 ft., for transom lashings	4	216	29	8	512	68
1½ in. circ., 36 ft., for ledger and brace lashings	10	360	27	14	504	37
1 in. circ., 21 ft., for road bearers	10	210	7	10	210	7
Spun yarn	..	..	7	..	..	7
Aggregate length and weight of rope required	..	2,442	526	..	2,882	575

From Engineer Field Manual.

For bridging a shallow ravine or watercourse, some one of the following lashed trestle bridges is applicable:

The *Two Legged Trestle* consists of a lashed frame as used for a single lock bridge, the standards being set at a greater slope. Each trestle is assembled on shore, carried out to the head of the completed bridge and let down by inclined skids until its feet are in position. The top is then pushed out by means of the stringers, previously lashed to the transom, the flooring is completed out to this point, the skids placed in position, and another trestle brought out and placed. See bottom of Fig. 57.

The *Three Legged Trestle* contains bents of two tripods each. The three legs of a tripod are lashed together at the top by means of two *shear lashings,* three ledgers are lashed around the bottom to keep the legs spread, and a transom is lashed on the inside face of each tripod. The road bearer rests upon the two

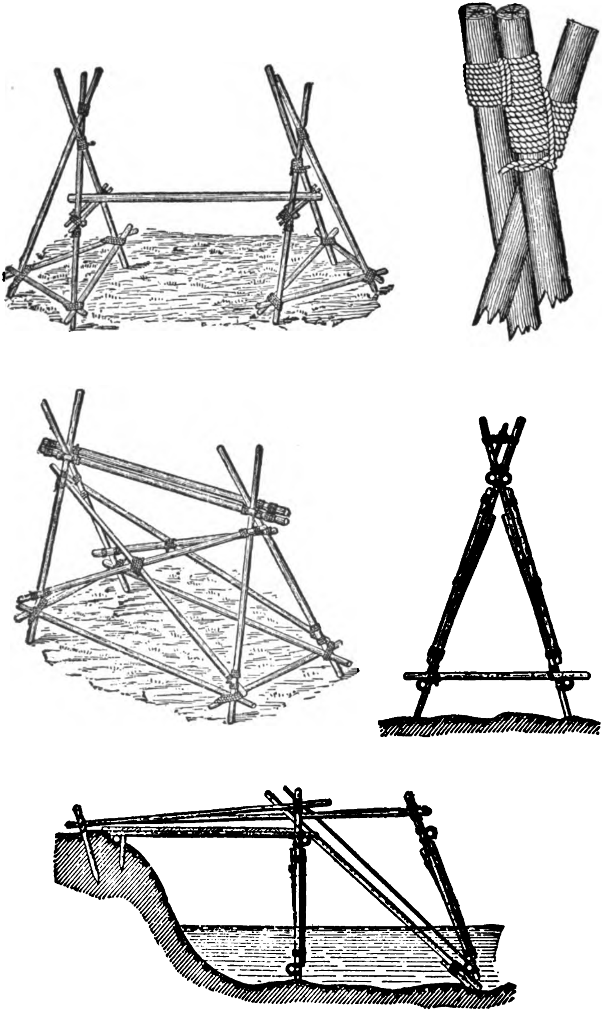


FIG. 57. LASHED TRESTLE BRIDGES

transoms. This type is built in place, the men wading in the water. It is impracticable in deep water, as the tripods are liable to float before the load is placed upon them. See top of Fig. 57.

The *Four Legged Trestle* is constructed in place, or, if of light spars, it may be carried out and placed in position. See Fig. 57, center cut.

SPARS AND LASHINGS FOR TRESTLES.

Kind of trestle.	No. of spars or lashings.	Length.	Diam. of spars or circ. of rope.	Purpose.
		Ft.	Ins.	
Two-legged..	2	....	4½ to 6	Legs.
	1	10 to 14	5¾ to 7	Transom.
	2	....	3½ to 4½	Diagonals.
	1	....	3 to 6	Ledger.
	6	30	1½	Lashings.
	3	15	1½	Lashings.
Three-legged.	6	....	3 to 5	Legs.
	1	14	7 to 8	Transom.
	4	4 to 6	3 to 3½	Cross bearers.
	6	6	1¾ to 2½	Ledgers.
	4	2	2	Stakes.
	12	30	1½	Lashings.
	6	15	1½	Lashings.
Four-legged	4	....	3¼ to4¾	Legs.
	2	10 to 14	5 to 6	Transom.
	4	....	3 to 3½	Diagonals.
	4	....	2½ to 3	Ledgers.
	12	30	1½	Lashings.
	6	15	1½	Lashings.

From Engineer Field Manual.

Floating Bridges.

Floating bridges are among the most important equipment carried by an army in the field. The equipage of the U. S. Army is of two kinds: the advance guard or light train, and the reserve or heavy train.

The *Light Train* is generally carried by engineers with the advance guard. The boats are collapsible, of wooden frames covered with canvas, and displace 6

tons. Each will carry 20 infantrymen fully equipped, and a crew. The boats are 21 ft. x 5 ft. 4 in. x 2 ft. 4 in., are spaced 16 feet center to center in the bridge, and the entire boat, with material for one *bay* or panel of the floor, is carried on one wagon. A division of the light train comprises eight boats and two trestles, spans 186 feet, and is carried upon 14 wagons, 8 ponton, 2 trestle, 2 chess, 1 tool, and 1 battery and forge.

The *Heavy Train* consists of wooden boats, 31 ft. x 5 ft. 8 in. x 2 ft. 7 in., displacing 9½ tons, and capable of carrying 40 infantrymen and a crew. They are spaced 20 feet apart, center to center, in the bridge, and one wagon carries a boat with the stringers for spanning one bay. A division of the reserve train comprises 8 boats and 2 trestles, spans 225 feet, and is carried upon 16 wagons, 8 ponton, 2 trestle, 4 chess, 1 tool and 1 battery and forge. Fig. 58 shows a loaded ponton carriage of the reserve train.

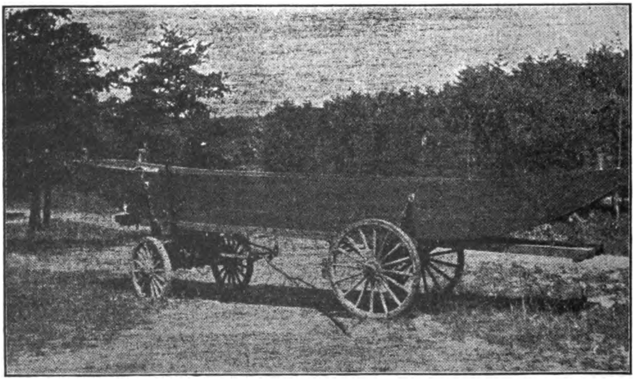


FIG. 58. LOADED PONTON CARRIAGE, RESERVE TRAIN

The *Floor System* consists of long stringers or *balks* which span between and across both boats, the *chess,*

which form the floor, and the *side rails,* which are extra balks laid on the outer ends of the chess to keep them down. The side rails are lashed to the balks under the chess, the latter being made narrower at the ends to allow passing the lashing between them. The floor is designed to fail before the boats can be sunk by a load on the bridge, and will safely carry 660 pounds per linear foot in the reserve equipage and 600 pounds in the light. Greater strength is obtained by using extra balk under the wheel tracks, and the factor of safety of the boats may thus be reduced from 4 to 2. Any load which travels with the army, including siege artillery, may then pass over the bridge.

NAMES AND DIMENSIONS OF THE PRINCIPAL PARTS OF THE LIGHT AND HEAVY TRAINS.

Name of part.	Light train.	Heavy train.
Ponton, 9½ ton...	....	31 ft. by 5 ft. 8 in. by 2 ft. 7 in.
Canvas ponton, 6 tons	21 ft. by 5 ft. 4 in. by 2 ft. 4 in.	
Balks and side rails	22 ft. by 4½ by 4½ in.	27 ft. by 5 by 5 in.
Trestle balks	....	21 ft. 8 in. by 5 by 5 in.
Chess	11 ft. by 12 by 1½ in.	13 ft. by 12 by 1½ in.
Abutment sills	....	14 ft. by 8 by 6 in.
Trestle caps, 2 planks each	....	20 ft. by 12 by 2 in.
Trestle legs	....	15 ft. by 7 by 3½ in.
Trestle shoe	....	
Suspension chains.	....	½ in. by 8 ft.
Paddles	8 ft.	
Oars	....	18 ft.
Boat hooks	8ft., blunted points	10 ft.
Rack sticks	1¼ in. diam. 2 ft. long	1¼ in. diam., 2 ft. long.
Anchor	75 lb.	150 lb.
Anchor cable	3 in. circ., 180 ft. long	3 in. circ., 240 ft. long.

Name of part.	Light train.	Heavy train.
Lashings	1 in. circ., 18 ft. long	1 in. circ., 18 ft. long.
Canvas-ponton cover.....	No. 0000 cotton duck	
Ponton chest	8 ft. long, 2 ft. 4 in. wide, 18 in. deep	

From Engineer Field Manual.

WEIGHTS OF WAGONS AND THEIR LOADS.

Kind of wagon.	Light train. Wagon. Lbs.	Light train. Load. Lbs.	Light train. Total. Lbs.	Heavy train. Wagon. Lbs.	Heavy train. Load. Lbs.	Heavy train. Total. Lbs.
Ponton	1,750	1,985	3,735	2,200	2,900	5,100
Chess	1,750	1,856	3,606	1,750	2,280	4,030
Trestle	1,750	2,060	3,810	2,200	2,635	4,835
Tool	1,700	1,938	3,638	1,700	2,100	3,800
Battery and forge	2,081	600	2,681	2,081	600	2,681

From Engineer Field Manual.

To save one boat at either end, and in places where a boat would ground, the *Birago Trestle* (Fig. 59) is

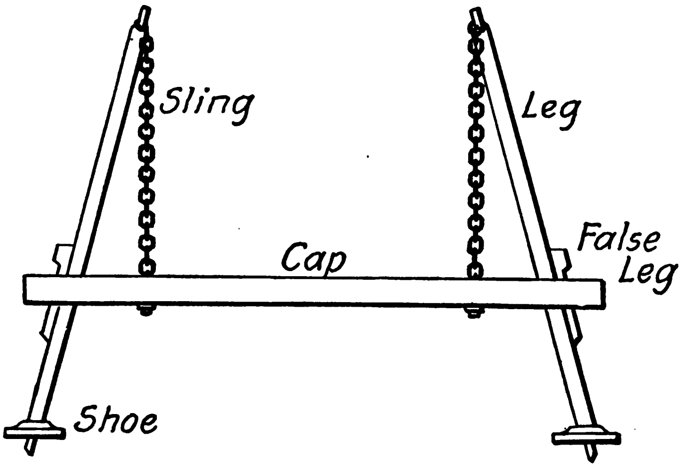


FIG. 59. BIRAGO TRESTLE

used. On dry ground or in very shallow water it may be assembled prone and raised into position by guy ropes. Over water it is assembled on a ponton raft and raised to the vertical, the cap resting upon two balks which project over the edge of the raft. The trestle balks are passed out from the shore and their double cleats hooked over the cap and the abutment sill on the bank. The shoes of the trestle are then forced down upon the bottom, the *false legs* or wedges driven, the chain slings adjusted, and the raft withdrawn. Chess are laid out to the trestle cap and the construction of the bridge proceeds as when building out from the shore. At the far end the trestle is placed in a similar manner, any surplus length of bridge being taken up by allowing a short bay between the last boat and the trestle or by setting the abutment sill back from the bank. The new *Rees Trestle* does away with the chain slings.

When there are not sufficient boats available to construct a bridge, some form of extemporized floating support must be constructed. Figs. 60 and 61 show, respectively, a barrel raft and a log raft. Before using such a raft, its buoyancy must be tested or computed, in order that it may not sink when the bridge is loaded.

In constructing the bridge, the boats are assembled, half upstream and half downstream of the abutment. The chess are piled on the right, the balks on the left, and the company is formed and divided into working parties as shown in Fig. 62. The first boat is brought from downstream to the bank (or alongside the trestle if used). The *balk carriers* bring out five balks, hook their cleats over the outer gunwale of the boat, where they are held in position by the *balk lashers* in the boat, and push it out until the cleats at the shore end of the balks engage the abutment sill (trestle cap or boat previously placed). The boat is then secured by cables to the bank. The *chess carriers* bring out the

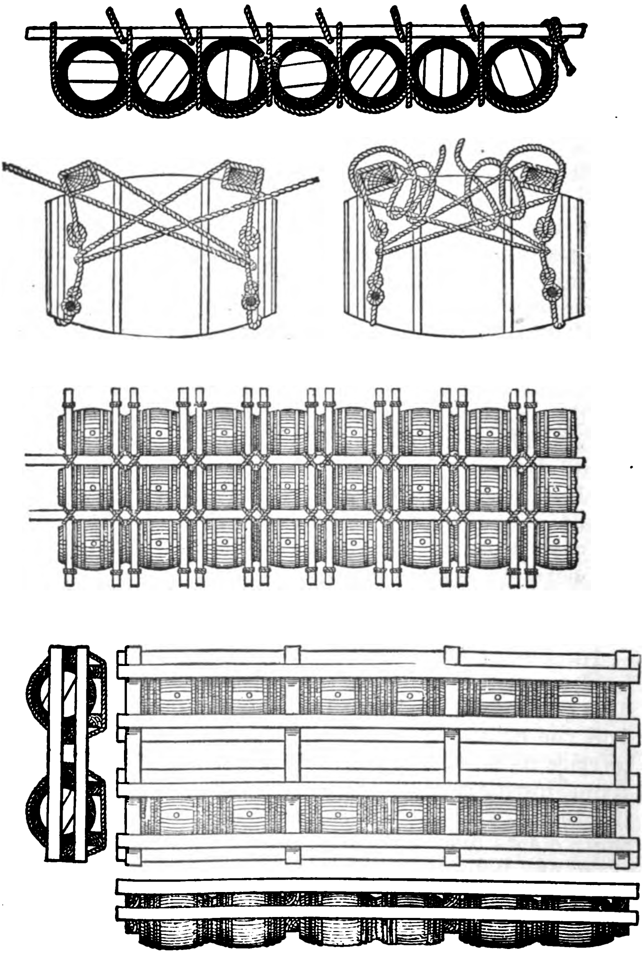


FIG. 60. BARREL RAFT

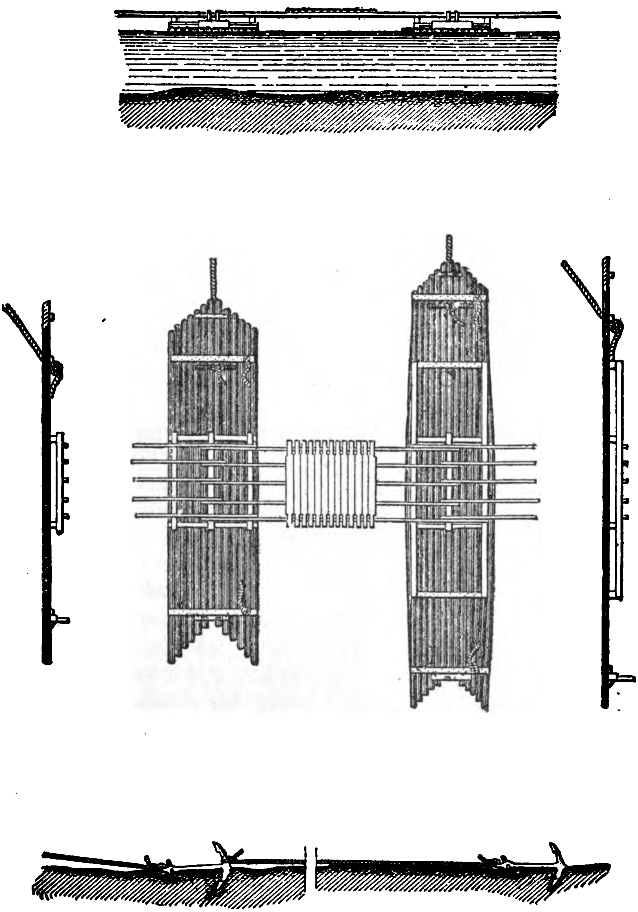


FIG. 61. LOG RAFT

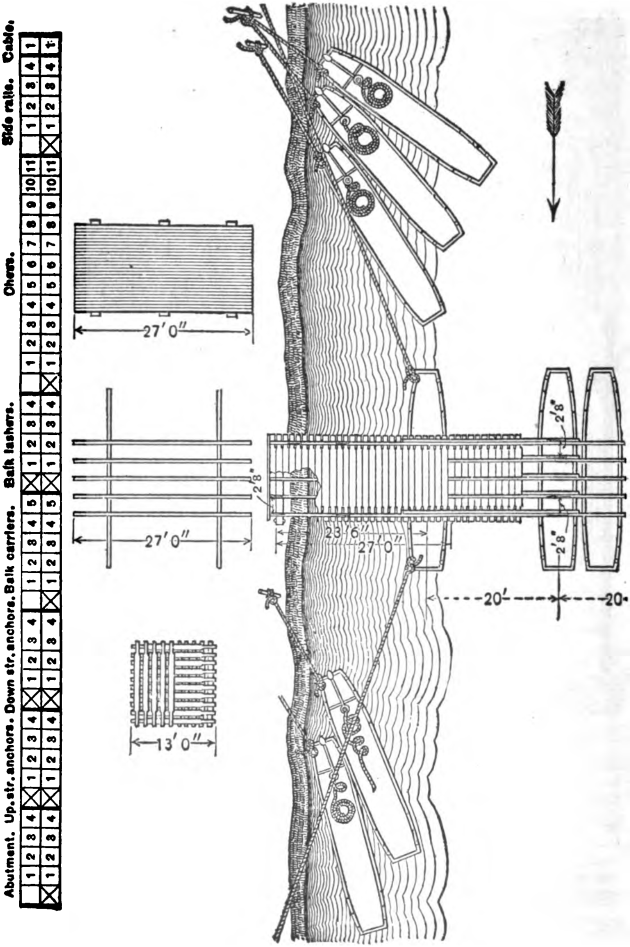


FIG. 62. FLOATING BRIDGE BY SUCCESSIVE BAYS

chess, which are laid across the balks out nearly to the first boat.

Boat No. 2, from upstream, drops its anchor opposite the position which will be occupied by *boat No.* 3 in the bridge, drops down alongside No. 1 and is pushed out as before. Both sets of balk are now lashed to the gunwales of No. 1 and chess laid out nearly to No. 2. The *side rail* detail place the side rails on the chess of the first bay, pass a lashing between the chess, around balk and side rail several times, insert a *rack-stick* in the loops and twist the lashing tight.

Boat No. 3, from downstream, drops anchor below its position on the bridge, comes alongside No. 2, takes the cable of the *upstream anchor* dropped by No. 2, is pushed out to position, and draws *both* anchor cables taut.

The construction of the bridge thus proceeds by the method of *successive bays,* and in the completed bridge alternate boats are anchored both up and down stream, the intermediate boats having no anchors. The balk, which are double over the boat and firmly lashed together and to each gunwale, preserve the requisite stiffness of the bridge.

To save time the method of construction *by parts* is sometimes adopted. (Fig. 63.) Different working parties construct a number of sections or *parts,* consisting ordinarily of three boats. These are floored over, excepting the outer boats of each section. Side rails are placed aboard but not lashed, and sufficient balk and chess are loaded to complete the flooring over the outer boats and over one interval between boats. One by one, these sections are brought to the bridge head, having first dropped their anchors or had them carried out by independent boats. The section is pushed out to the proper interval as in the case of a single boat, and the flooring completed with the extra chess. This method gains considerable time, and re-

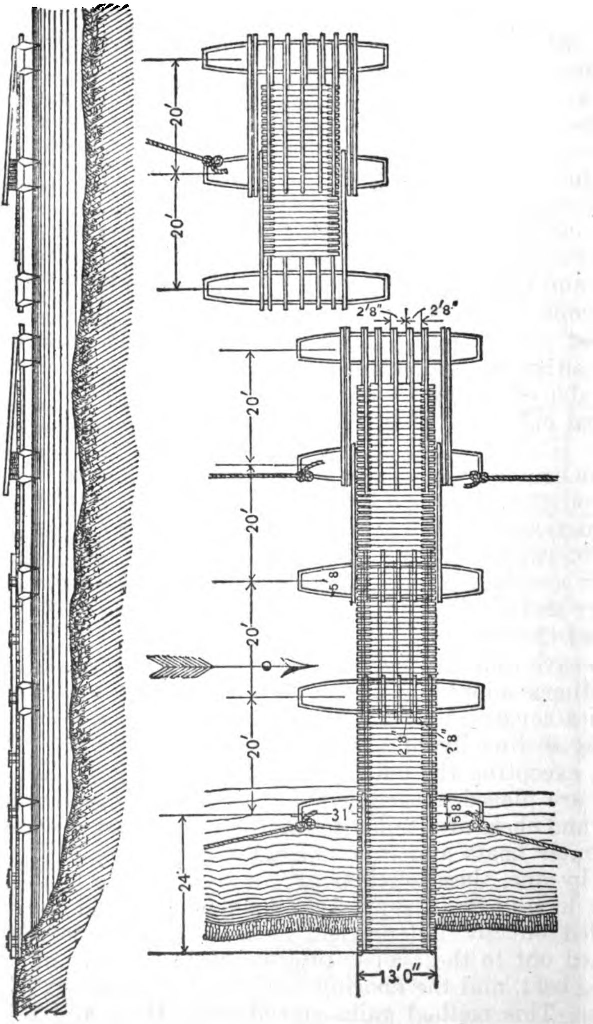


FIG. 63. FLOATING BRIDGE BY PARTS

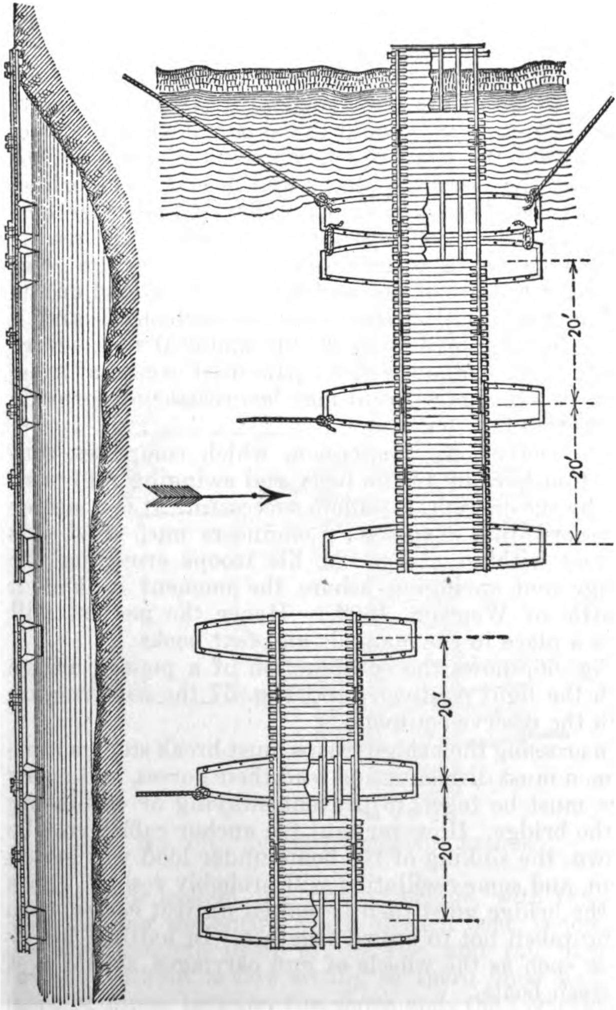


FIG. 64. FLOATING BRIDGE BY RAFTS

sults in a completed bridge identical with that constructed by successive bays.

The method by rafts is occasionally used, where boats are plentiful and extreme haste is necessary. (Fig. 64.) A *raft* is similar to the *part* described above, except that the chess are laid complete, from end to end, and the side rails placed and lashed. The bridge is constructed by lashing a number of rafts together, the end boats of each resting side by side. The resulting bridge is not satisfactory, as the piers are composed alternately of one and two boats. A load on the bridge, therefore, causes unequal settlement, and a heavy moving load subjects the material to a severe strain. The method is very little used except at some point in a bridge where it may be necessary to provide a draw. (Fig. 65.)

The method *by conversion,* which comprises construction parallel to the bank and swinging into position by the current, is seldom successful. It is a matter of record that Napoleon's engineers once used this method with great success, his troops crowding the bridge and springing ashore the moment it landed. (Battle of Wagram, 1809.) Hence the method still finds a place in the manuals and text books.

Fig. 66 shows the construction of a ponton bridge with the light equipage, and Fig. 67 the construction with the reserve equipage.

In crossing the bridge troops must break step, mounted men must dismount and lead their horses, and every care must be taken to prevent swaying or oscillating of the bridge. However taut the anchor cables may be drawn, the sinking of the boats under load will loosen them, and some oscillation will probably result. Those on the bridge must then be halted until it ceases, care being taken not to crowd together. In halting, heavy loads such as the wheels of gun carriages, should rest between boats.

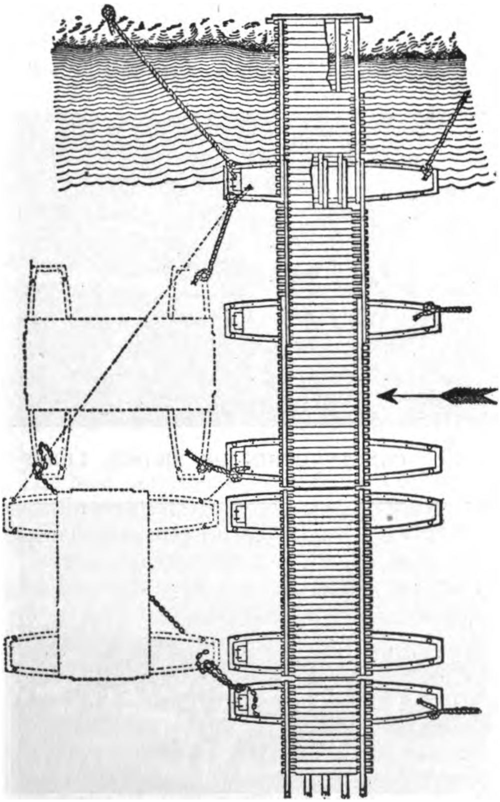


FIG. 65. DRAW IN PONTON BRIDGE

The floor system of a ponton bridge, with the balk overlapping the entire width of each boat, is too stiff to accommodate itself to the rise and fall of tidal waters without severe strain, so there must be some sort of hinge between the shore end, the elevation of

which is fixed, and the floating portion. This may be accomplished by placing a *saddle sill* over the axis of the first boat, so that the balk join at this sill and do

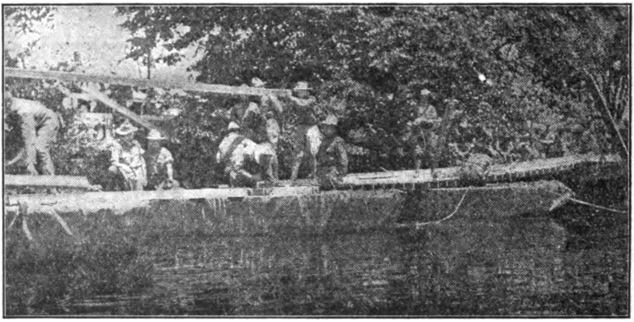


FIG. 66. CONSTRUCTION OF BRIDGE, LIGHT TRAIN

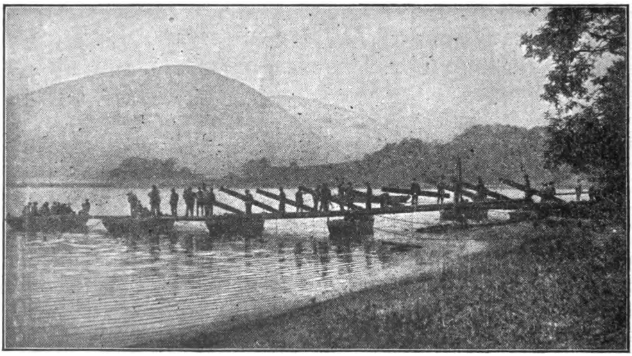


FIG. 67. CONSTRUCTION OF BRIDGE, RESERVE TRAIN

not have two points of support at the gunwales. Lacking such a sill, the shore balk may be ended at the near gunwale of the first boat, letting the balk of the second

bay extend entirely across the boat. The cap of the Birago Trestle cannot serve as a hinge, as it lies at a fixed elevation the same as the abutment sill.

To load pontons of the reserve train on their carriages, four methods are practiced.

1st. The rear wheels of the carriage are dismounted, and the boat pushed up the incline formed by the seven balk already in place on the wagon trucks. The wagon is then jacked up, and the wheels replaced.

2nd. The rear wheels are backed into a depression, usually dug out for the purpose, and the same proceedure followed.

3rd. Balks may be placed from the ground at the side of the wagon and the boat pushed up the incline thus formed, over the wheels and into place. This is the least to be recommended of any of the methods here described.

4th. The best method is to provide a barrel-shaped roller of sufficient strength (a strong barrel may be used if guided properly), place it in front of the boat, back the wagon up to within 10 or 12 feet, and push or pull the boat up over the roller and on the wagon. Such a roller may be made and carried along with the train, in one of the boats.

Where the ponton train is to be moved by rail, flat cars are used, and the number required is computed as follows: a 40-foot flat car will accommodate one ponton or trestle wagon and one chess, tool or forge wagon. A 34-foot car will carry one ponton or trestle wagon or two of the shorter wagons. A division of the reserve train, therefore, will require ten cars, of which six must be 40 feet in length, the others shorter. The distribution is as follows:

Four cars, 40-ft., one ponton wagon, one chess wagon on each.

One car, 40-ft., one ponton wagon, one tool wagon.

One car, 40-ft., one ponton wagon, one forge wagon.

Two cars, 34-ft., one ponton wagon each.

Two cars, 34-ft., one trestle wagon each.

If only 34-ft. cars are available, 13 are required, as below:

Ten cars, one ponton or trestle wagon each.

Two cars, two chess wagons each.

One car, one tool and one forge wagon.

To load the wagons, two strong skids are provided, each about 16 feet long, a foot wide, built with a side rail, and having hooks at the upper end to engage the iron sleeves on the car. These skids are placed at the end of the train, their centers blocked up, and the intervals between cars bridged. Or, an incline may be constructed of the ponton flooring. The wagons may be hauled up by about twenty-five men, walking along the cars, or a snatch-block may be rigged at the end of the first car and the pull made along the ground, by men or teams. The rope is attached to the running gear of the wagons, secured by a half-hitch near the end of the tongue for guidance, and a couple of men walk up the skids guiding the tongue. The wagons must be brought up in their proper order, a small wagon ahead of each ponton or trestle wagon on a 40-ft. car. After hauling up, the wagons are taken over by details of men and run along the train to their positions. Each wheel is blocked front and back, and additional blocks are placed outside each wheel, and connected by 2x4's passing between the spokes. The latter may be replaced by pieces of old brake hose, passing through the wheels and nailed to the car floor outside and inside each wheel. Tongues are removed and made fast under the wagons to which they belong.

In detraining, the wagons are best let down the skids by snubbing the rope on a post formed by driving a

piece of 4x4 timber into one of the iron sleeves at the front end of the car.

The entraining or detraining of a division of the ponton train should be accomplished in about 1½ hours, with ordinary troops, under competent supervision. If a long loading platform the height of the cars is available, the wagons may be loaded from the side, a number at once, and in much less time.

It is a popular opinion that the ponton bridge is like a picture puzzle, each part cut and fitted, and easily assembled. On the contrary, each bridge built is a separate problem, which calls for much hard labor and considerable ingenuity. Highly trained troops are required to operate the train and skilled mechanics to maintain it in condition for immediate use.

XIII.

TOPOGRAPHICAL SKETCHING.

HOW DIFFERING FROM SURVEYING METHODS.

Military sketching differs from the ordinary operations of surveying chiefly in the time required and the accuracy of the completed work. An error of 10 or 15 per cent. in the length of a road will not make so much difference to the commander if he can tell from the sketch *about* the time it will take to march the distance, whether the grades are practicable for his trains, and something of the topography on either side. Nor is the exact height of a hill of so much importance as its *shape,* whether there is dead space on its slopes, where it is too steep to assault, etc.

To the average engineer, the contours on a map are simply the statement of a mathematical problem; given: these contours, required: to compute excavation, locate gradients or balance cut and fill. To the military engineer, they mean *ground forms,* and his problems deal with dead space, visibility and command. It is often of vital importance to know whether a certain stretch of road is visible from an observation station, over the top of an intervening hill. Upon the correct solution of this problem depends the sending of troops by that route when their movements must be concealed from the enemy. The engineer, in making his map, works for accuracy, determining the location and elevation of ruling points and drawing the contours among them. The military sketcher works to *picturize information,* traversing the drainage lines as a skeleton and building around them by contours the ground forms which he sees.

Major Sherrill, in his "Military Topography," says: *No man can become an excellent sketcher until he involuntarily sees the map forms which would correspond to the ground observed; nor can he be a perfect map reader or scout until to see a map is at once to picture to himself intuitively the ground forms from which the map was made.*

Sketches must be made rapidly. The information must be turned in at the end of each day's march, and the sketcher must keep pace with an infantry column covering 2½ to 3 miles per hour. To sketch at this rate and deliver a contoured map with all required information necessitates careful training and considerable practice.

It is certain that nothing in the way of a topographical survey can be undertaken in the field during hostilities, even by reconnaissance methods. The information would not be available as soon as wanted, and the sketchers could not advance in front of their own forces to map the ground on account of interference by the enemy. For the proper conduct of operations on a large scale, therefore, dependence must be placed upon maps prepared before war is declared, and the great usefulness of the sketcher lies in the correction and amplification of existing maps, and in making road maps and position sketches covering small areas. The very fact that topographers must stay with their own troops, has the effect of limiting their usefulness to a great extent. They cannot map a position until it is occupied, therefore the information contained in their sketches can be of no use in effecting the occupation, and similarly as regards mapping a road in time to route the line of march. However, sketchers with reconnaissance patrols may be able to gain quite a distance to the front and turn in sketches which, while fragmentary, may, in conjunction with existing maps and fragments turned in by others, furnish very

useful information to the commander. No feature of the terrain that might be of military value, therefore, should be overlooked by the sketcher, whether that value be apparent to him or not. An engineer would not think of designing a foundation without the fullest information regarding the site, but the military commander can never be fully informed. He must consider all the information that he has, sift the true from the false as well as he is able, and base his action upon the partial knowledge that remains.

INSTRUMENTS USED.

The small plane table, about 14 inches square, with a compass needle set in one edge and mounted upon a light camera tripod, is the most useful instrument for mapping. The map is made complete as the survey progresses and nothing is left to fill in or to be completed later, as the sketch must be turned in at the end of each day, as soon as camp is reached, to begin the work of matching and reproduction.

The *sketching case,* Fig. 68, is a small plane table, intended to be used without a tripod. In use, it is strapped to the wrist or carried in the hand, and is for that reason particularly adapted to mounted sketching. A compass is mounted in the top edge of the board, and two rollers are provided to keep the strip of paper stretched. A map much longer than the board may be drawn by rolling up the completed sketch on one roller and feeding fresh paper from the other. The *alidade* is in the form of a jointed brass ruler, pivoted to the top edge. The board may be used to read vertical angles by loosening the pivot screw of the alidade, holding the board in a vertical plane and sighting across the screws at the top, allowing the alidade to swing freely. The angle is read on the scale at the base of the board. The cover of the compass can be revolved by a stud set at one side, and two

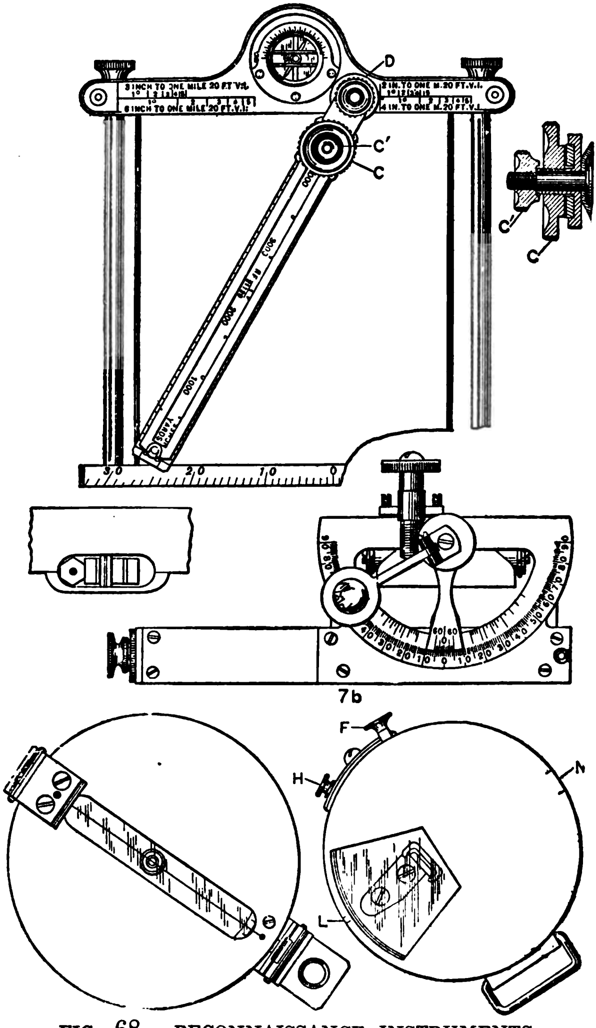


FIG. 68. RECONNAISSANCE INSTRUMENTS

parallel wires are mounted on the cover glass, revolving with it. In commencing a sketch, the board is pointed in the desired direction, the needle allowed to come to rest, and the wires revolved to a position parallel to the needle. They must not be again moved during the making of the sketch. In taking each sight, the board must be oriented by turning it until the needle comes to rest between and parallel to the two wires, or swings equally on each side of their axis. In sighting, the board is not raised to the height of the eye and the alidade aimed at the point, but is held in front of the body and the ruler pointed by looking alternately at the point and the ruler, as in plumbing down from a high point by eye. In Fig. 68 the detail at the right is of the clamp screw on the alidade. Loosening the small top screw C^1 permits revolving the lower link about the pivot, while the large screw C controls the motion of the pivot along the slotted upper link. The lower detail shows the end of the pencil slot under the board.

Below the sketching case, Fig. 68, is shown the *Abney Clinometer*, used to read vertical angles. The line of sight through the tube is divided, half of the object end being open, with a horizontal wire across its center, the other half is closed by a diagonal mirror, permitting a view of the bubble which is mounted above the tube. The bubble and the target can thus be seen at the same time, and if the bubble is brought to the center, the graduated arc will give the angle of elevation or depression. The clinometer may be used as a hand level by clamping the circle at zero and keeping the bubble in the center of its tube while sighting.

The *service clinometer* (lower right-hand corner of Fig. 68), is used for the same purpose, but depends upon a weighted pendulum in place of a bubble. The line of sight is through the eye hole, L and the orifice N. A small mirror is mounted at the center of the

instrument and reflects to the eye a circular scale mounted on the pendulum and illuminated by the glass window shown. The scale is graduated in degrees and is seen at the same time as the target, so that the vertical angle is read direct. When the scale reads zero the line of sight is level and the instrument may be used as a hand level. The pendulum is released to revolve by pressing the button F which, in turn, may be locked by pushing forward the slide H. This instrument is quicker of operation, but not so accurate as the Abney type. It is sufficiently accurate, however, to meet all requirements of military sketching.

The *prismatic compass* (lower left-hand corner of Fig. 68) is used to read bearing or azimuths, the card being usually graduated to read clockwise 360 degrees from the north. The cover lifts to a vertical position and forms the front sight. The prism turns up over the edge and forms the rear sight, allowing at the same time a view of the edge of the compass card, rotating beneath it. A push button under the front hinge stops the card at will, so by checking it in the middle of its swing it may be more quickly brought to rest.

The *aneroid barometer* is used to find differences of elevation. It gives best results when the start and end of the survey are at points of known elevation, allowing interpolation for intermediate points, or when used in conjunction with a standard barometer read regularly at one station to register atmospheric changes.

METHODS.

The plane Table is set up at the starting point, oriented by compass, and the position of the first station is assumed on the board, having due regard for the direction in which the sketch will proceed and the area to be covered. With the edge of the alidade passing through this initial point, a pointing is made towards the next station and a line drawn along the edge. Sim-

ilar sights are taken and lines drawn in the direction of various features which it is desired to locate upon the map. The distance to these points may be measured by pacing or may be estimated, or a second sight taken towards them from another station, the intersection of the two giving the location. Angles of elevation or depression may be read by the clinometer, as an aid to contouring. When ready to move, the board is taken up and the sketcher walks towards the second station, counting his paces or keeping a record of them with a *pace tally,* which is a watch-shaped counting device held in the hand and actuated by pressing the stem at each stride or step. As he proceeds he keeps mental or written notes that at 90 paces a house was passed, 30 paces to the right of the road, at 145 paces a stream was crossed on a wooden truss, 40 ft. long x 16 ft. wide x 12 ft. high, at 181 paces a railroad was crossed at grade, making an angle of 60 degrees with the road, etc. Upon arriving at the next station the board is set up, and oriented by compass or by backsight. Using a scale of his own paces, he first plots the distance between the stations along the line already drawn, thus locating Station 2. The notes taken along the way are then plotted, then a sight taken to the next station, and to various side points. The survey proceeds by repeating these operations.

Mapping is done with a soft pencil upon vellum tracing paper, or, in wet weather, upon sheets of celluloid, roughened on one side to take pencil lines. Sketches upon this material are not damaged by rain.

The sketching case is used in exactly the same manner as the sketching board, except that it cannot be oriented by backsights unless placed in a steady position upon a fence post, the ground, a stone, etc. Maps drawn with the sketching case are not so accurate as those made with the sketching board, as the pointings or orientations cannot be made so closely.

The *Prismatic Compass* is useful in running traverses for control, or to obtain bearings to important objects. If used for filling in, it either takes two men, one to read bearings and the other to plot and sketch, or one man must do both and take twice as long, or the plotting must wait until the reconnaissance is completed and must be done out of sight of the ground to be sketched, which means that more elaborate notes must be taken to aid his memory.

The Engineer Note Book, Figs. 69 and 70, shows a method once much used. The two plates are almost self-explanatory. The record is started at the bottom on the left-hand page, the record of distances and the alignment is kept in the center column, also azimuths of side shots. In the columns on either side of the center are placed the offset distances, and in the outer columns the descriptions. Azimuths are read by the prismatic compass. On the right-hand page, Fig. 70, is shown the plot of the notes in Fig. 69.

Contouring.

For assistance in contouring, a device known as a scale of *map distances* is used. On a map of a given scale contours of, say 10 feet interval, are spaced a certain distance apart on a 1 degree slope. On a map of half the scale this distance is reduced one-half, but on a map of *half* the scale and *twice* the contour interval, the contours will be spaced the same distance apart for a 1 degree slope as in the first map. Similarly for slopes of different degrees.

In the U. S. Army, three principal scales are used for sketching, as follows.

Nature of sketch.	Scale.	Representative fraction.	Contour interval.
Road sketch........	3 in. = 1 mile	1 : 21 120	20 Ft.
Position sketch	6 in. = 1 mile	1 : 10 560	10 Ft.
Fortification sketch.	12 in. = 1 mile	1 : 5 280	5 Ft.

Remarks Left.	Offsets Left.	Courses & Distances	Offsets Right.	Remarks Right.
Crossed wagon road		1230	230	Road running N.&S.
running E.& W.		4° R.		through Alpine
Crossed dry Cr.		880		village.
Cr.	12	100	230	Farm H.
Cult.		18°00'		
		⊙5		
		3256		
		$7^h 41^m$		
R.R.Br.	100	4000		
Cr.	25	3080		Crossed dry Cr.
		2765		Crossed wagon road
Cr.	2	2465		Crossed dry Cr.
R. R. Br.	100	2300		
R. R Br.	250	1760		
		1660	200	Farm H.
		1650		Crossed Wagon road
				running E. & W.
Creek 30 wide	440	620		
Woods along Cr.				
		34°00'		
Rolling Prairie		⊙4		Pasture
Pasture		1230		
		$7^h 4^m$		
Farm H.	110	800		
Farm H.	150	600		
		450		Crossed wagon road
		230	160	Farm H.
		15° R.		
		303°00'		
Corn & Wheat		⊙3		Corn & Wheat
		1530		
		$6^h 50^m$		
		1230		Crossed Cr. 15 wide
Creek, dry run	130	880	175	Farm H.
		3° F.		
		343°00'		
		⊙2	50	Farm H.
Left wagon road		230		Cult.
Cult.		$6^h 33^m$		
Farm H.	25	200		Level Country
		100	10	Farm H.
Left Mokena $6^h 30^m$ AM.		0°00'		Following wagon road.

Sept. 4th. 1900. $6^h 30^m$

⊙1 All distances in Yds.

Beginning

FIG. 69. ENGINEER NOTE BOOK

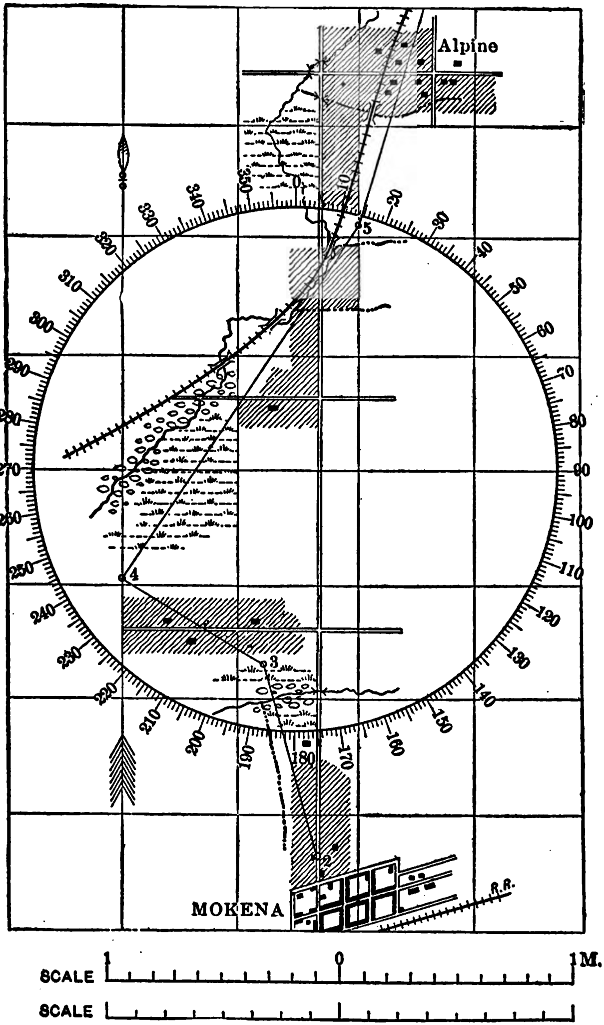


FIG. 70. ENGINEER NOTE BOOK

It will be noted in this table that as the scale is increased the contour interval is reduced in like ratio, so the same map distances will apply to maps of all three scales. (Fig. 71.) The use of this scale is simple

Scale 1 : 5280 - V. I. = 5 ft.
" 1 : 10560 - V. I. = 10 ft.
" 1 : 21120 - V. I. = 20 ft.

FIG. 71. SCALE OF MAP DISTANCES

and will often obviate the necessity of referring to a table to find differences of elevation.

A hill to the side of the road is located by intersection and plotted. The slope from the station to its summit is measured by a clinometer or slope board and found to be 2 degrees. It is then determined by trial how many times the map distance for 2 degrees will fit into the plotted distance to the hill. This figure gives the number of contours which must be drawn between the two points on the map, and, multiplied by the contour interval, gives the difference of elevation. If the slope between the points is uniform, the contours are spaced equally, according to the map distance. If flat for half the distance, no contours are drawn in this half and the total number are crowded into the other half. If the slope is concave the contours will show it by being drawn closer together near the summit and *vice-versa*.

Figs. 72 and 73 show the ordinary topographical symbols used in military mapping. When pressed for time, the sketcher will not fill in a space with symbols, but will draw a wavy line around it and write "Woods," "Cult.," etc. inside.

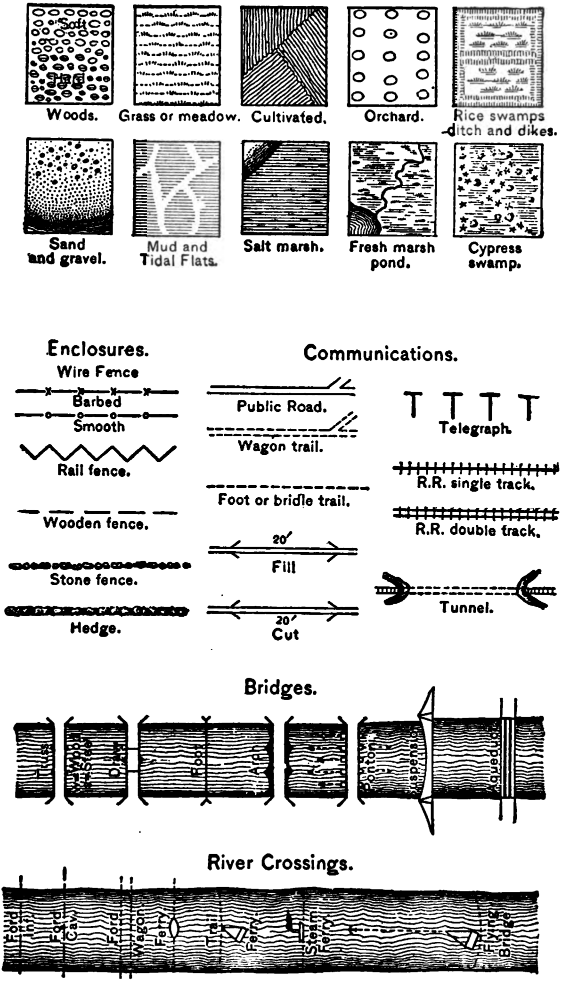


FIG. 72. TOPOGRAPHICAL SYMBOLS

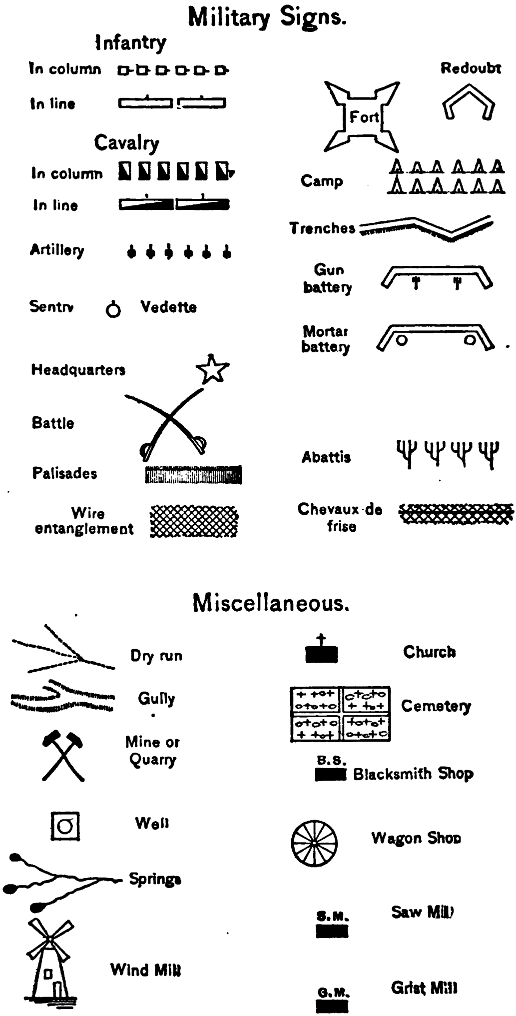


FIG. 73. TOPOGRAPHICAL SYMBOLS

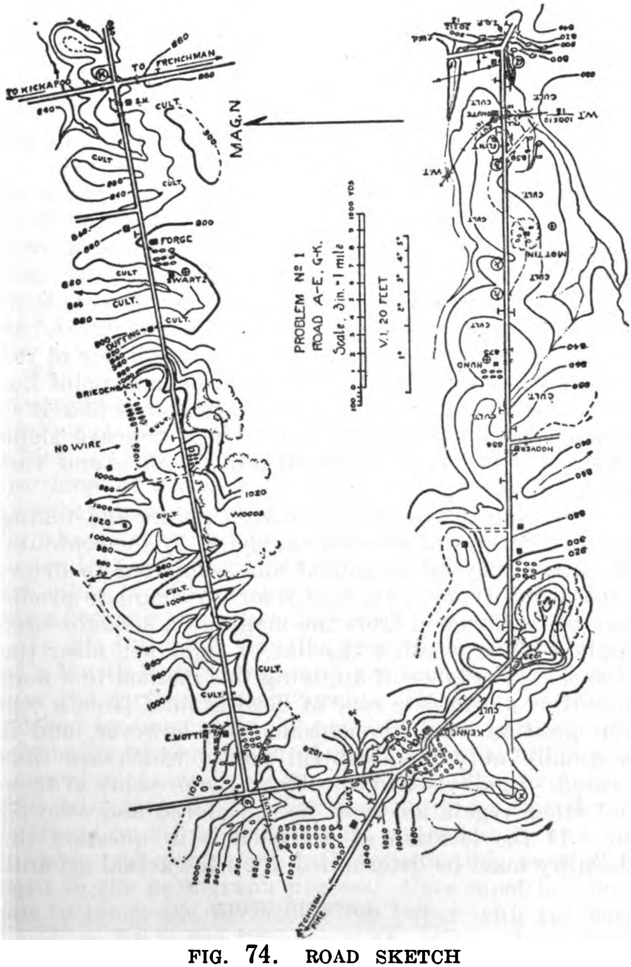


FIG. 74. ROAD SKETCH

Fig. 74 shows a road sketch reproduced from Sherrill's "Military Topography" which will give a fair idea of the character of work done.

VISIBILITY.

One of the problems which confront the military man in reading maps is the determination of the visibility of one point from another. This is of importance in laying out a field of fire to avoid dead space, and in movements of troops which must be concealed from the enemy. The problem can sometimes be solved by inspection, as when the difference of elevation of the points in question is large and the intervening point is not much higher than the lower of the two, or when the height of the intermediate point lies about halfway between the two end points and it is situated nearer the high end. On a concave slope points will be visible from all other points, and vice versa.

By scaling the distances between points and taking their differences of elevation as shown by the contours, the slopes may be computed and compared to determine visibility, or, as a final resort, a complete profile may be constructed from the map and a straight-edge applied to see whether the line of sight will clear the obstacle. The labor of applying this method to a map to outline a complete zone of dead ground from a certain position would be considerable, however, and it is usually only the doubtful points which are thus treated. In all visibility problems the presence of trees and other vegetation must be considered and allowed for. If the location of a trench is in question the visibility must be determined upon the actual ground.

MAP REPRODUCTION.

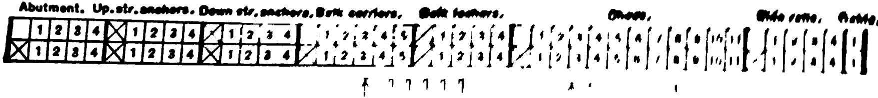
When the sketches are turned in at night, they are matched, closures forced by cutting and pasting, and

the whole combined sketch is reproduced for sending out with the orders for the following day. In operations involving large bodies of troops, maps are needed in considerable numbers, and it becomes necessary to employ a method of reproduction which is rapid and capable of producing work in quantity.

Blue-printing is about the simplest process, but is very slow, especially when done at night under such artificial light as is available in the field, so a lithographic method has been developed for field use, differing from true lithography in that a zinc plate is used instead of a stone. The process is called *zincography* and the machine with which the work is done is called the *zincograph.*

The equipment consists of a working table, a press resembling a large clothes wringer, an ink roller, the various chemicals and solutions used, and the container, which is a large three-storied chest, in the upper compartment of which is stored the press, and in the lower two the solutions and supplies. There are two processes by which drawings may be reproduced, one of which is dependent upon sunlight or some strong artificial light, the other of which requires no such light but necessitates copying the entire drawing to be reproduced.

In the latter, or transfer process, the zinc plate is of a No. 19 B. & S. gage, and has been so treated as to give the surface a slight grain. This may be accomplished by immersing the polished plate in a solution consisting of one gallon of water, two oz. nitric acid (commercial) and one oz. of alum. The result is a dull satin gloss finish. The drawing to be reproduced is traced on a thin coated india paper known as autographic transfer paper, with transfer ink, such as is used in the hectograph process. Care must be taken not to touch the surface of the paper with the bare hand, as the natural grease of the skin will cause all finger prints to be reproduced in the finished print.


Abutment.
Up.str.anchors.
Down str.anchors,

tion poured over it, the surplus being allowed to run off.

Printing is now done by moistening the plate with damp cheese cloth, inking it with the roller, covering it with the paper and running it through the press. The first print can be obtained in from 15 to 30 minutes after the tracing is made, depending upon the amount of building-up required by the ink lines. For rapid printing two men are required. No. 1 dampens the plate, No. 2 inks it with a hard roller from an ink slab, No. 1 inserts it in the press and No. 2 turns the crank of the press. Copies can be printed at the rate of six per minute.

The second process depends upon contact printing, and requires a strong light, preferably the sun. As most of this work in the field must be done at night, however, this process will not be much used. The plate is sensitized with a solution consisting of 120 grains of dry albumen or the white of one egg, 15 grains of ammonium dichromate and 7 oz. of water. The plate must be thoroughly cleaned before applying the sensitizing solution, and after the latter has dried the plate must not be exposed to the light. A maduro negative must first be made of the map to be reproduced, which may be printed from the patched-up field sketches. The plate is then placed in a printing frame with the negative, which latter must face *away* from the plate, to insure lettering, etc., reading correctly on the finished print. The exposure depends upon the intensity of the light, and also upon the transparency of the negative, varying from 10 to 15 minutes. The progress of the printing may be observed by opening the frame at intervals, care being taken not to alter the relative positions of the plate and the negative.

Immediately upon removal from the printing frame, the whole plate is covered with ink from the roller, to prevent further action by light. It is then developed

The tracing is then placed between two moistened sheets of blotting paper until it has become thoroughly dampened. It is now ready to transfer to the plate.

The dampened drawing is placed face down on the grained surface of the zinc plate, which is then run through the press several times, moistening the drawing at intervals with a wet sponge. The paper can now be peeled off, leaving the ink lines on the plate. The plate is dried by fanning and then covered with a thin coating of gum solution, which is made by boiling one pound of dextrine in a pint of water. The plate is then given a coat of ink, applied with a piece of cheese-cloth, and sponged with water. The latter operation removes the ink from that portion of the plate not occupied by the lines of the drawing. If these lines do not now show up well, the operation is repeated until all lines are well defined. Any line that has not transferred to the plate may be drawn upon it with a pen or a fine brush. While the plate is still damp from the last sponging, it is worked over with the ink roller, the ink from which adheres to the lines, but may be easily wiped off from the damp portions of the plate. After removing the surplus ink, the plate is dusted with powdered resin and again sponged with water.

In order to print from the smooth plate, it must be treated so the ink from the roller will adhere to the lines and not to the remainder of the plate. Ink will take on a greasy surface but not upon one which is damp, and in order to insure a moist surface on the plate, it is etched with nitric acid and the etched portion filled with gum, to which the ink will not adhere. The etching solution consists of 4 oz. of nitric acid in two gallons of water. The powdered resin is only a partial protection for the ink lines, therefore the plate must not be left in the etching solution more than about one minute. Upon removal from the acid, the plate is sponged with water, dried, and the gum solu-

tion poured over it, the surplus being allowed to run off.

Printing is now done by moistening the plate with damp cheese cloth, inking it with the roller, covering it with the paper and running it through the press. The first print can be obtained in from 15 to 30 minutes after the tracing is made, depending upon the amount of building-up required by the ink lines. For rapid printing two men are required. No. 1 dampens the plate, No. 2 inks it with a hard roller from an ink slab, No. 1 inserts it in the press and No. 2 turns the crank of the press. Copies can be printed at the rate of six per minute.

The second process depends upon contact printing, and requires a strong light, preferably the sun. As most of this work in the field must be done at night, however, this process will not be much used. The plate is sensitized with a solution consisting of 120 grains of dry albumen or the white of one egg, 15 grains of ammonium dichromate and 7 oz. of water. The plate must be thoroughly cleaned before applying the sensitizing solution, and after the latter has dried the plate must not be exposed to the light. A maduro negative must first be made of the map to be reproduced, which may be printed from the patched-up field sketches. The plate is then placed in a printing frame with the negative, which latter must face *away* from the plate, to insure lettering, etc., reading correctly on the finished print. The exposure depends upon the intensity of the light, and also upon the transparency of the negative, varying from 10 to 15 minutes. The progress of the printing may be observed by opening the frame at intervals, care being taken not to alter the relative positions of the plate and the negative.

Immediately upon removal from the printing frame, the whole plate is covered with ink from the roller, to prevent further action by light. It is then developed

in water, as in the ordinary blue print process. While still immersed in the water the ink may be wiped off with cheese-cloth. When fully developed the plate is removed from the water and dried by fanning, then dusted with powdered resin, the surplus of which is wiped off. The process of etching and printing then proceeds as in the first method.

The plate may be prepared for further use by removing the ink with turpentine and washing thoroughly with lye. Regraining is necessary only after the plate has been used a number of times.

The first method is better adapted to field use, but the second will do finer work. It is even possible to reproduce photographs by printing from a film or negative on the sensitized plate.

The zincograph is a part of the equipment carried by the engineer battalion in the field. Each company is equipped with a clay *hectograph,* from which about 50 copies can be made from one impression.

The sketch is copied in transfer ink, laid face down upon the level clay surface and allowed to remain for one or two minutes. Printing is done by laying blank sheets of paper on the clay, smoothing them out and taking them off immediately. Sketches may be reproduced by this method in three colors.

LANDSCAPE SKETCHING.

Sometimes information may be better conveyed by a landscape sketch than by a map, particularly as to relief. It may take a great deal of mapping to make clear what can often be shown by a few strokes of the pencil. The sketch also has the advantage of showing in detail just what points it is desired to bring out, leaving non-essentials out entirely or subordinating them to the important points. A photograph cannot do this, as it must show all that is before

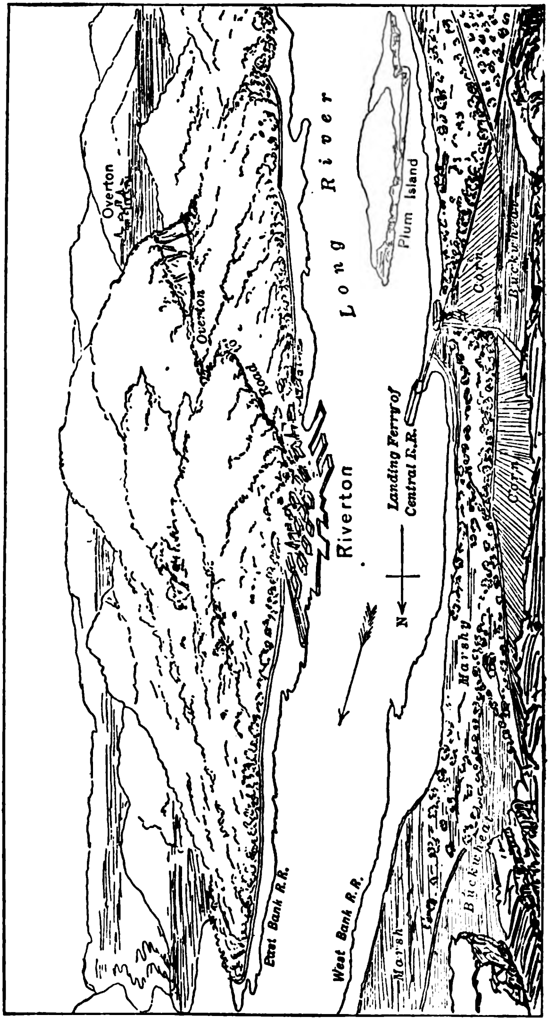


FIG. 75. LANDSCAPE SKETCH

the camera, and in its very accuracy and fidelity to actual conditions, the military information which it is desired to emphasize may be entirely lost.

Fig. 75 is an excellent example of a sketch of this character, reproduced from the Engineer Field Manual. This shows features which would have necessitated actually traversing the terrain and the expenditure of much time to show on a map, and even then the information would not stand out at a glance as it does in the sketch.

In making a sketch of this character the pad is held out in front of the eye until it covers the area intended to be drawn. Then, lowering it slightly, the position of the various hill tops, road crossings, etc., which it is desired to show are marked off on the upper edge of the pad. Similarly, the vertical distances are marked off on one side of the pad. The co-ordinates of all the important points are thus determined and the completion of the sketch consists of connecting these points and filling in such detail as may be required. Heavy lines are used for outlines of objects in the foreground, medium for those at mid-distance and light for distant objects.

An excellent treatise upon the subject is M. Lefebvre's "Military Landscape Sketching," translated by Capt. Judson, Corps of Engineers, U. S. Army, and published as "Occasional Papers No. 3" by the Engineer School, Washington Barracks, Washington, D. C.

CHAPTER XIV.

FIELD FORTIFICATIONS—ADDENDA.

With the constantly increasing volume and accuracy of artillery fire in the European War has developed the ingenuity of those subjected to this fire in contriving expedients to protect themselves.

The close proximity of hostile trenches, quick changes from defensive to offensive and the reverse, and the dense concentration of troops upon the western battle front have all tended to convey the impression that the art of fortification was undergoing a radical change. The principles of field fortification, however, do not change; it is only in the details and manner of applying these principles that variations may be observed.

PROJECTILES

The developments in projectiles have been along the line of artillery projectiles of greater searching power, of aerial mines and of grenades.

Artillery Projectiles.

Artillery projectiles are given greater searching power by increasing the angle of their bursting sheaf.

A common shrapnel bursts with a sheaf of 14°. Half this, added to the angle of fall of the shell, 11° at 3,000 yards, fixes 18° or about one upon three as the angle of fall of bullets and fragments at this range. Upon narrow trenches and overhead cover, therefore, the searching power of such a projectile is small.

The German 77 m.m. high explosive shell bursts with a hollow sheaf of 114°, so that its fragments have considerable effect in searching deep trenches, the

angle of fall being about 65°. The fragments are effective at a distance of fifteen yards from the burst.

The German 105 m.m. combination shell, however, bursts with a hollow sheaf of 200° of shrapnel bullets and splinters, while the nose of the shell, containing a charge of high explosive, continues on its course and explodes upon impact. The shell bursting upon the ground, or the nose alone, will scatter fragments in all directions. They are effective at a distance of twenty-five yards. When fired from a mortar, this shell, with its wide bursting angle and steep fall, is very effective in searching out space provided with overhead cover. Such a shell bursting immediately in rear of a trench is extremely dangerous to the occupants, unless they are protected by a substantial parados.

The following table gives the overhead cover required for protection against high explosive shell, with percussion fuse, from the various German field pieces. Where logs and earth are specified, the former should be in two layers, one to support the earth, the other at or near the surface, to cause the shell to burst by impact before penetrating the earth. A layer of rails or stones will be even more effective. This detonating layer should preferably be covered with some earth, to prevent its being scattered by the bursting shell. It is said that cover composed of two layers of 12-inch logs, separated by one foot of earth, has successfully resisted six-inch high explosive shell.

Piece	Cover Required.
77 m.m. (3″) gun	3 ft. to 4 ft. earth.
105 m.m. (4″) mortar	7 ft. to 10 ft. earth.
150 m.m. (6″) howitzer	2 ft. 6 in. logs, 2 ft. earth.
210 m.m. (8″) howitzer	3 ft. 6 in. logs, 3 ft. earth, rails, stone, etc.
280 m.m. (11″) howitzer	17 ft. to 33 ft. undisturbed earth.

Aerial Mines.

Aerial mines, thrown from catapults or trench mortars, contain charges of high explosives varying from 2.2 to 110 pounds. They detonate upon impact, and are used principally on account of their destructive effect upon opposing trenches. They will break down traverses and overhead cover, and cave in trench walls, destroying firing parapets and obstructing communications.

Grenades.

Grenades are the standard weapon for trench fighting. They are maiming rather than fatal in their effects, are terribly effective, and are very difficult to guard against. They were at first made by the troops themselves, from jam tins, pieces of pipe or plank, etc., and were often as dangerous to the thrower as to the enemy. They are now an article of manufacture and issue, and are of many types. The two principal classifications are as to the manner of projecting, by rifles and by hand.

Rifle grenades are fired from the service rifle, being either mounted upon a sort of ramrod which enters the barrel and is projected by a special blank cartridge (British type), or inserted in a special cylindrical cup which is fitted to the muzzle of the rifle and projected by the service cartridge (French type). Both these grenades are of the percussion type, exploding upon impact. They have a range of 250 to 350 yards.

Hand grenades may be of the *percussion, ignition* or *mechanical* type. In the former the firing pin is at the front end, and the bomb is provided with streamers or "tails" to insure its striking head on. Such bombs are usually prepared for throwing by removing a safety pin, thus freeing the firing

plunger. Their principal danger lies in striking the firing pin on the parados in the act of throwing, thus causing a premature explosion.

The *ignition* types require lighting of their fuse before throwing. This may be done in the various types by (1) removing a safety cap and striking the fuse on a friction pad held in the left hand or worn upon the sleeve, (2) forcibly withdrawing a friction tube from the bomb, or (3) attaching the ring of a friction primer in the bomb to a lanyard looped around the wrist, so that the act of throwing the grenade ignites the fuse. The usual ignition bomb has a five-second fuse, and where the range is short it must be held two or three seconds before throwing, otherwise it may be thrown back by the enemy.

The *mechanical* type contains an interior fuse ending in a detonator and ignited by a cap resting under a spring plunger. This plunger is prevented from falling by a lever fitting in a groove on the outside of the bomb and held in place by a safety pin. The pin is removed after taking the bomb in the hand preparatory to throwing, the pressure of the hand clasping the lever to the bomb case. As the latter is cast, the lever is released, the plunger drops upon the cap, and the fuse is ignited. This type is one of the most satisfactory and successful of those used.

Protection against grenades is effected: first, by keeping enemy bombers at a distance of forty or fifty yards, extending the entanglements to this distance and filling in all approaches within this radius that can afford cover to a bombing attack; second, by giving to all parapets and embankments a slope away from the trench, so that grenades falling upon them will not roll into it; third, by erecting sloping screens of wire netting or other material over the parapet, of such height that bombs clearing it will fall behind the trench; fourth, by providing individual recesses in

the parapet (Fig. 23, p. 94), thus limiting the sphere of action of the bomb; and fifth, by unceasing vigilance and activity on the part of the defenders' grenadiers.

TRENCH DETAILS

Developments Due to Close Contact. When enemy trenches lie within a hundred yards or less, as in many localities along the western front in Europe, concealment is often no longer possible, and everything is subordinated to strength and protection. Heavy parapet sections, head and overhead cover, and other devices usually considered inimical to concealment, are in common use. Bomb screens, made of wire netting, and always very conspicuous, are a necessity at such close quarters, to prevent the enemy's throwing hand grenades into the trench.

A development of this sort of warfare is the *self-supporting* trench, i.e., one which is capable of sheltering not only its proper garrison, but sufficient supports to reinforce the firing line and to replace casualties. This is rendered necessary by:

1. The comparatively short distance to be travelled by the enemy in charging the fire trench, and
2. The device of *barrage fire* or the *curtain of fire* which is directed at a belt between a fire trench and its supports to prevent the bringing up of reinforcements at a critical moment.

Not only, therefore, must the supports be sheltered in or very near the firing trench, but the regular garrison, which is usually kept in the rear during the artillery bombardment which precedes an attack, must be kept in the front line. This necessitates overhead cover for both parties until the artillery fire is lifted preparatory to the infantry assault.

This may be provided in two ways:

First, by reducing the distance between fire and

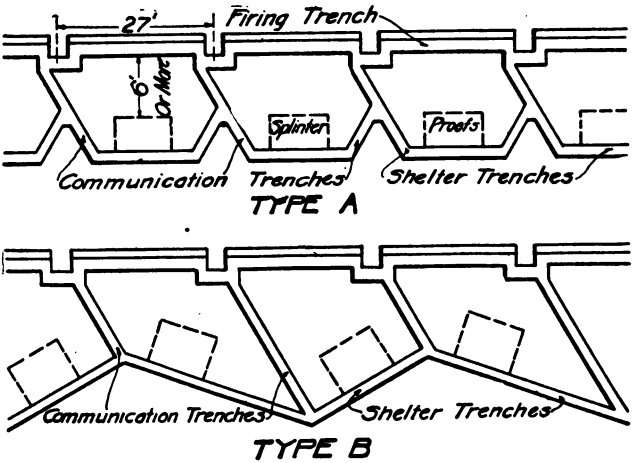


FIG. 76. SHELTER TRENCH CLOSE IN REAR OF FIRE TRENCH

shelter trenches, as in Fig. 76, with frequent communicating trenches.

Second, by constructing the front line trench with overhead cover, splinter proofs, trench shelters, dug-

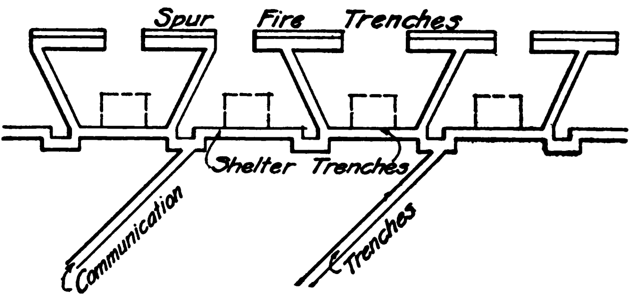


FIG. 77. SPUR FIRE TRENCHES

outs, etc., and even with loopholes for observation, sniping, etc., and extending narrow spur trenches, without head or overhead cover, to the front, from which trenches infantry attacks are met and sorties and counter attacks made. (Fig. 77.)

The cover constructed in the front line trenches

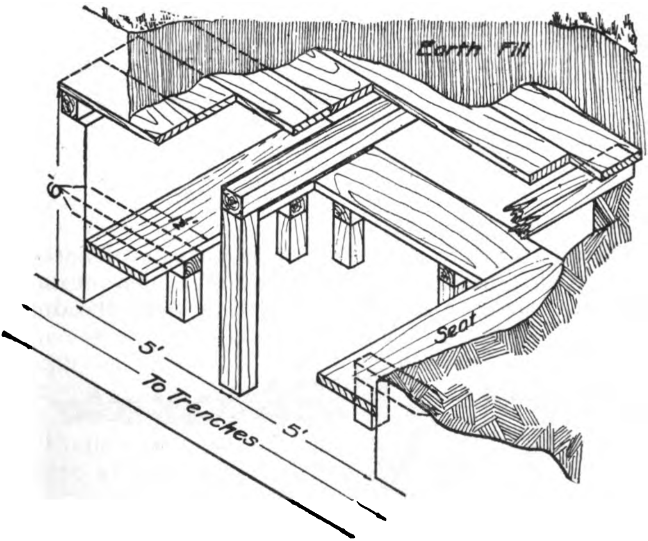


FIG. 78. SPLINTER PROOF

may take various forms, *a splinter proof,* for about a squad of men (Fig. 78), a *trench shelter,* in which men may lie at length and be protected during sleep (Fig. 79), or a dugout, which is a very deep, completely timbered excavation under the parapet (Fig. 80), in which a portion of the trench garrison may live, protected from all but the heavy explosive shell. These dugouts sometimes develop into very complete

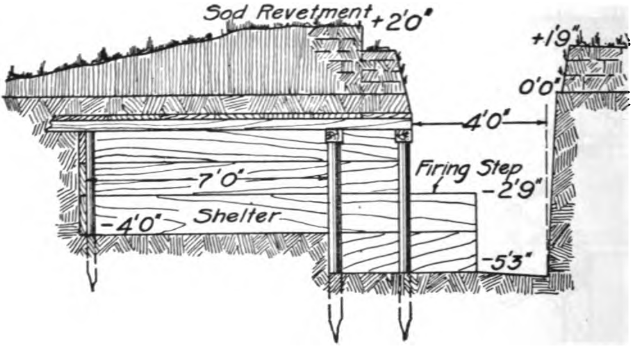


FIG. 79. TRENCH SHELTER

underground barracks. Their principal disadvantage lies in their vulnerability to bomb attack. The enemy, upon capturing a trench, will always bomb the dug-

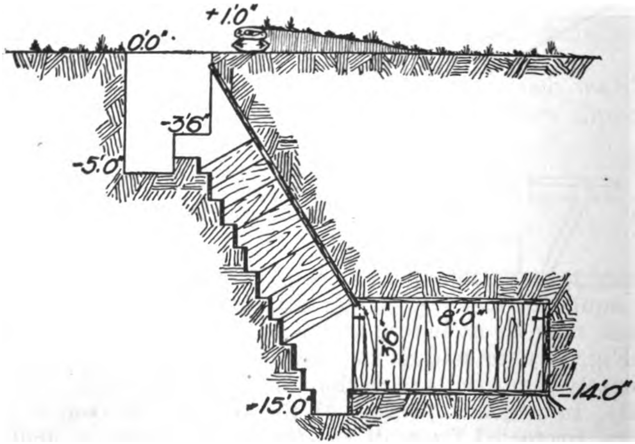


FIG. 80. DUGOUT

outs as a matter of routine, in order to protect his rear from reverse fire after passing on. This objection may be overcome in a way by constructing the entrance passage with two turns in its length. Usually, however, the steepness of the passage will insure that a bomb thrown in from above reaches the dugout, or, at the most, the enemy will be put to the trouble of advancing to the first turn to hurl his grenade.

Each dugout, or *cave shelter*, should be provided with two exits, in case one is blockaded by falling earth. These two entrances should not be upon opposite sides of a traverse, as both might be closed by a direct hit upon the latter by a large shell.

A very good reason is advanced for placing such shelters out in front of the trench, under the entanglements. The enemy, in attempting to destroy the latter, times his shell to explode at the ground surface or slightly above, to obtain the full effect of the explosion among the wires. The earth cover of the dugout is therefore not greatly injured, as the shells do not penetrate before exploding. The efficiency of a shallow roof may be greatly increased by placing a layer of hard material, logs, rails, stone, etc., at or near the ground surface to cause early bursts. In order to leave a roof of undisturbed earth, as well as to avoid rehandling of the earth, these shelters are constructed by the methods of military mining. (p. 118.)

Overhead cover of the splinter proof variety is objectionable in a fire trench. It is always falling in under bombardment, not only injuring the men underneath, but destroying a length of firing parapet at a critical time, just when an attack is imminent. This is not a vital objection in shelter trenches, from which ordinarily no fire will be delivered, and where there is sufficient space to construct this cover in

small units, so that little damage is done by each direct hit.

There is a strong tendency among the defenders of a trench to cower under overhead cover, if at hand, or to dive into dugouts, as its capture becomes imminent. Their annihilation follows as a matter of course. To insure that the defense will be vigorously prosecuted until the last, therefore, all such cover should be banished from the trench in which the attack is actually to be met. Means should also be provided for quickly leaving the trench in case of a sortie or counter attack. (See p. 98.) An effective device for this purpose is shown in Fig. 81.

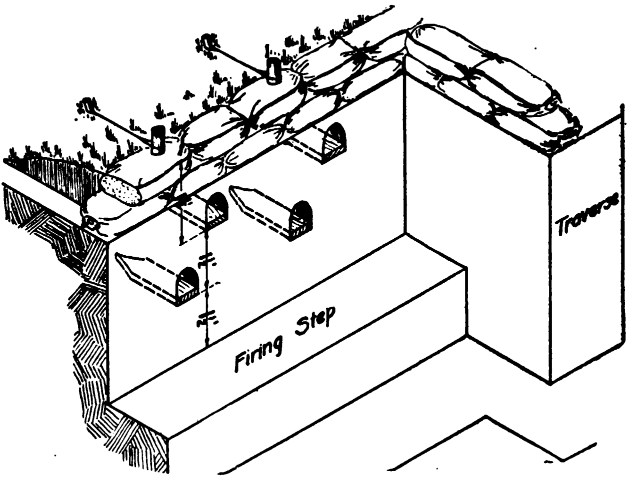


FIG. 81. SORTIE STEPS IN FACE OF TRENCH

At the preparatory signal for attack, the soldier takes his rifle in the right hand, seizes the stake with his left and places his left foot in the lower step, crouching so that his head is below the parapet. At

the signal to attack he straightens up, places the right foot in the upper step, then the left upon the parapet, and advances to the front. (Fig. 82.) To avoid splitting off the face of the parapet when a

FIG. 82. LEAVING TRENCH BY SORTIE STEPS

man's weight is thrown upon these stakes, they should be anchored back by wires to a second stake built into the parapet. If necessary for concealment or protection, the stakes may be set in a small recess cut into the rear face of the parapet, although they will stand considerable rifle fire. In the trenches con-

structed by the 22nd N. Y. Engineers at McAllen, Texas, 1916, such a stake, two inches square, and projecting four inches from the ground, withstood a test of twelve shots fired through it without becoming unserviceable.

Fire Trench Cover. No form of cover so far devised can safeguard a fire trench against high explosive shell. The best that may be done is to provide cover from shrapnel, rifle and machine-gun fire, to present as small a target as possible, to avoid undue

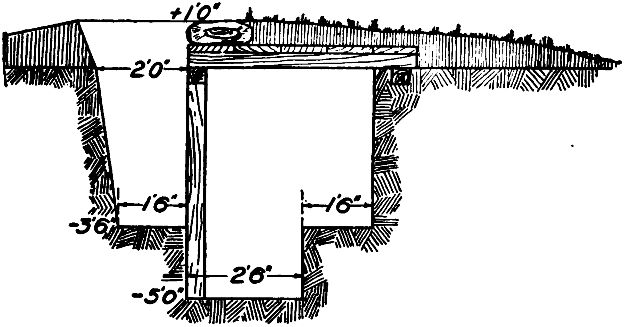


FIG. 83. TRENCH WITH COVERED PASSAGEWAY

concentration and to seek concealment from the enemy's artillery observers. The following types are suitable for trenches from which fire is to be delivered, but which are not to be used for resisting an infantry assault, as the main trench in Fig. 77, and shelter trenches designed for auxiliary fire.

A deep narrow trench, with a strong parados, will protect its occupants from the black blast of high explosive shell, and a direct hit is usually necessary to inflict much damage. The effect of such a hit is localized by frequent traverses and parapet recesses. It has been found, however, that the advantage gained

by very narrow trenches is counteracted by the difficulty of maintaining communication along them when occupied. The types shown in Fig. 21, p. 92, and Fig. 27, p. 97, eliminate the crowding, but present too wide an opening. Fig. 83 shows a type affording overhead cover to both garrison (when not fir-

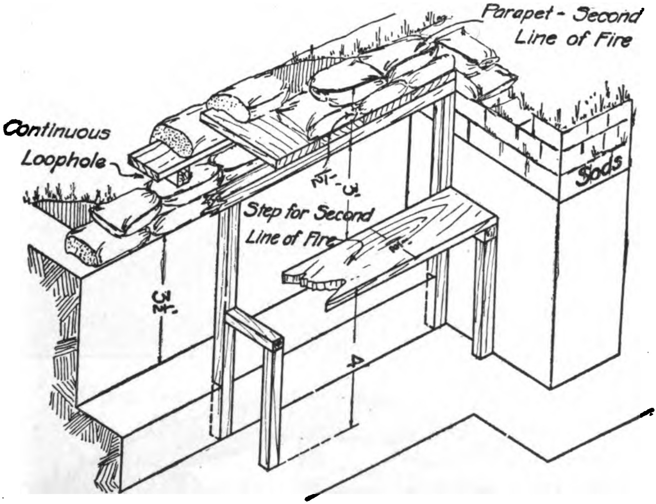


FIG. 84. CONTINUOUS LOOPHOLED TRENCH, DOUBLE LINE OF FIRE

ing) and passageway, but presenting no wider opening than a simple standing trench. In such a type the passageway would probably tunnel through the traverses instead of encircling them.

Fig. 84 is a loopholed trench with overhead cover to protect the occupants while firing, with provision for a second line of fire from the step in the rear. The loophole shown is of the *continuous* type, which

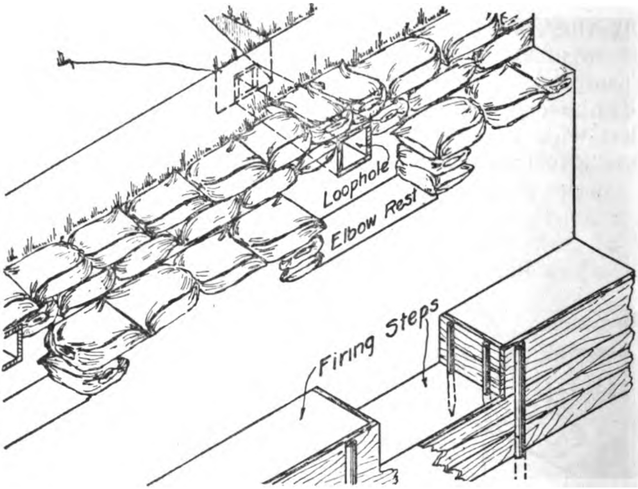


FIG. 85. TRENCH FOR FIRE THROUGH AND OVER PARAPET

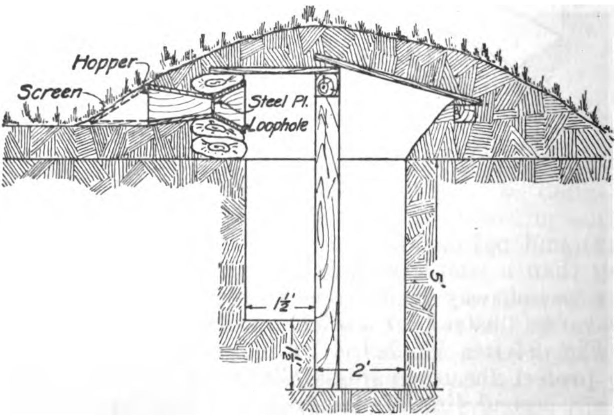
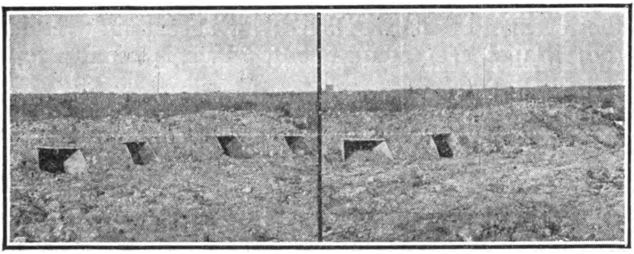


FIG. 86. INCLOSED TRENCH

is difficult to conceal, but permits a wide field of fire.

Fig. 85 shows a trench designed for a small regular garrison, provided with head cover and loopholes, but with a higher banquette between loopholes, so that in repulsing an attack the supports may man these raised sections and fire *over* the parapet.

Fig. 86 is an inclosed trench similar to Fig. 28, p. 98, but constructed with a type "C" loophole (Fig. 24, p. 95), and with a steel plate at its throat containing a T-shaped opening. From the front these



Open for Firing Shutters Partly Closed

FIG 87. HOPPER LOOPHOLES

loopholes are very conspicuous, showing black shadows (Fig. 87), so they are usually built with a light shutter, operated from the inside and lying upon the floor of the loophole when the later is in use. When closed these shutters or screens conceal the loopholes very effectively.

Loopholes. The type described above is useful for general firing only, in stopping an attack or in night firing upon a working party disclosed by a flare or other form of illumination. To occupy such a loophole for sniping or observation in daylight is suicidal, as it is most conspicuous when the shutter is lowered for use. Loopholes for this purpose are usually

placed obliquely to the front, and every care taken for their concealment. It is said, however, that with all possible precautions in their construction and use, they seldom remain undiscovered for more than a week, and once located they are speedily made untenable.

It is reported that the Germans place black sand bags at intervals in their parapets, rendering it very difficult to distinguish the true loopholes, whose shadows are so closely simulated by the dark colored bags. This device may be successful in concealing the location of the loopholes, but it certainly renders the parapet very conspicuous, which is usually to be carefully avoided.

A good loophole may be made by two steel rails tilted together, heads and flanges in contact. Fig. 88 (a). A very limited angle of fire is thus afforded, however, and if an attempt is made to increase it by separating the outer ends of the rails, the resulting loophole will collect bullets like a funnel, deflecting them to the eye end. Separating the inner ends, however, improves the cover, allows a larger angle of fire, and presents only a small opening to the enemy's observation.

The French use a steel parapet shield, 28 in. x 16 in., provided with a small loophole and two projecting feet, upon which a sand bag is laid to hold the shield in position. This shield is 0.45 inches thick and weighs 66 pounds. Fig. 88 (b). A more portable form, used by the soldier as cover for his firing and digging-in operations, is 20 inches square, 0.33 inches thick, and weighs 33 pounds. Fig. 88 (c).

Traverses require a greater thickness than formerly considered necessary. Three feet of natural earth, as ordinarily used, will stop rifle bullets, but will crumble away under machine gun fire. Furthermore, a direct hit by a high explosive shell will destroy any except a

very thick traverse. Thicknesses of seven to nine feet are no longer uncommon, and in many trenches as now laid out the traverses, with the passages around them, occupy as much space as the fire bays between. The fire trench may be further divided by recesses as

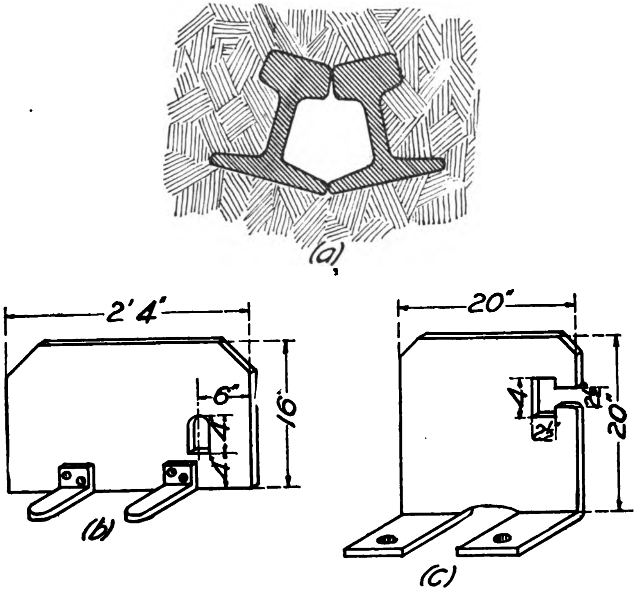


FIG. 88. LOOPHOLES AND SHIELDS

in Fig. 23, p. 94, for better protection against shell and grenades.

All this greatly reduces the available length of firing parapet, and is made possible only by the great development of fire from machine guns and automatic rifles, reducing the number of riflemen required to hold a given line.

This loss of firing parapet is sometimes partially compensated for by constructing *reversed traverses,* in which the trench is conducted around the front of the traverse instead of around the rear. This permits a greater length of firing trench, and a good position for a machine gun emplacement or an observing station is thus provided, but the passage in the front is not so safe as in the rear, and the riflemen in this position are in the way of oblique fire which may become necessary from adjoining bays. If such a construction must be adopted, it is better to make the passage in the rear, and the fire trench in front, thus forming a *detached* or *island* traverse.

A *caponiere* traverse, or *trench blockhouse,* is a thick hollow traverse, built of concrete and steel rails, with space inside for a small garrison. Its walls are pierced by loopholes for rifle and machine gun fire along the line of the trench. It is entered from a dugout or a passage under the parapet, opening into adjacent fire bays, and its purpose is to check the spread of an attack, particularly of bombing parties, along the trench.

Machine Gun Shelter. The tendency in machine gun shelters is towards the flanking fire type of emplacement. (Fig. 31, p. 101.) The increased security of the piece and the greater difficulty experienced by the enemy in locating the emplacement compensate for the loss of frontal fire. Furthermore, a burst of machine gun fire upon the flank of an attacking line, delivered as a surprise after silence during the earlier stages, is particularly demoralizing, and will often break up an apparently successful attack.

Emplacements are now usually built with overhead cover and loopholes. (Fig. 89.) The gun occupies the emplacement only when in use or when about to be used, and nearby shelter of the splinter proof type

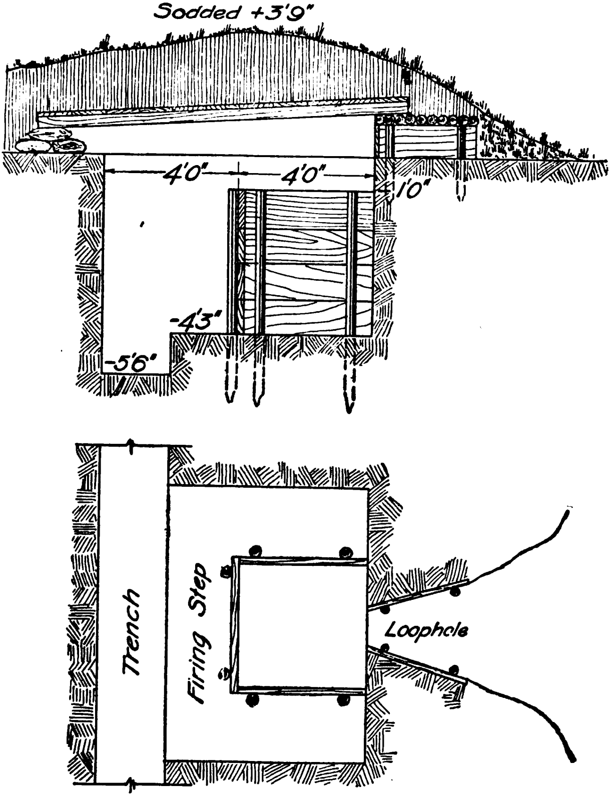


FIG. 89. MACHINE GUN EMPLACEMENT, OVERHEAD COVER

is provided for the gun and its crew during an artillery bombardment. The flanks of trenches and in rear of the intervals between trenches are the most effective machine gun positions.

For constructing emplacements in a line of trenches,

where concealment is difficult, concrete and steel rails are frequently used, and a structure is built which will withstand a heavy bombardment.

The French favor removing machine guns entirely from the infantry trenches, as they draw artillery fire. Their emplacements are often constructed in shell holes in front of the firing trench, and connected with the latter by a tunnel or sap. An irregular parados is thrown up to protect the gun crew from the fire of their own infantry, a gun platform is erected, and the front lip of the shell crater forms the parapet. The position is not occupied until about to fire, and there is nothing in the appearance of the position to distinguish it from numerous other shell holes in the vicinity.

Communicating Trenches. To save revetment, these are usually constructed with sloping sides, with a slight berm at the ground level to remove the weight of the parapet from the edge of the trench. They are revetted as maintenance requires, and usually become wider by repeated processes of caving and cleaning out. A wide trench is not so safe to pass through under fire, but may be travelled at a more rapid rate, thus keeping one for a less time in the danger zone. If constructed narrow, certain trenches should be designated for one-way traffic.

Lines of main communication should not cross, especially if they are liable to be used at the same time. Unimportant lines, however, may cross main lines, in which case confusion as to direction is avoided by making the main trench about a foot deeper at the intersection.

In case of the enemy's obtaining a foothold in the firing trench, the communicating trenches are arranged for a stubborn step by step defense as the enemy advances. The following methods of preparing for such defense are recommended:

The ground between the fire and support trenches is covered by entanglements, to insure that the attack will advance along the communicating trenches, rather than overland.

Recesses for bombers are placed behind the turns in the trench, from which the enemy is bombarded by grenades as he occupies the section ahead.

Portable or collapsible wire obstacles are placed in recesses at the sides, to be pulled into the trench by the retreating defenders.

Caponiere traverses are built across the trench at intervals, from which it is enfiladed by rifle or machine gun fire through loopholes. This is sometimes done from a recess built at the rear end of a straight stretch, entered by a narrow passage from the side of the next stretch in rear. Care should be taken that: (1) these recesses and traverses are provided with overhead cover, to deflect grenades; (2) that the loopholes are low, so the enemy cannot advance to them by crawling and throw in grenades or thrust through with a bayonet; (3) that the entrance to such recesses is not straight, otherwise the occupants might be injured by fragments of grenades exploding in rear.

Further to the rear, two main communicating trenches may be led to a junction, at which is placed a strong island traverse, performing the functions of the caponieres as described above. The passage leads around both sides of this traverse, so that no restriction of the traffic results, and there is the great advantage that either or both of the forward branches can be swept by fire, *i.e.*, the enemy may be held under fire in one, while the defending troops are still retreating through or contesting the possession of the other.

Dummy trenches leading into *cul-de-sacs* are run out from trench intersections to confuse the enemy.

These trenches bear the appearance of much travel, and misleading directions are placed at the intersection. A common device in connection with these dummy trenches is to gradually raise their floors, so that the enemy, in hot pursuit, suddenly finds his head above ground and under fire from neighboring support trenches.

Revetments. Revetting materials in most common use in Europe are: sand bags, corrugated iron, expanded metal, canvas, and planks. They are required in such enormous quantities that every effort is made to economize by sloping trench walls to make them self-sustaining, and revetting only for repairs or where absolutely required. Sand bags are the most common type, and form at least the upper part of nearly all fire trench revetments. In laying up a full revetment of sand bags, the foundation is excavated below the floor of the trench, and the bags laid up as carefully as first-class masonry. The bags are filled about two-thirds full, and are squared and flattened in place by mallets. The firing step is built up against this revetment, using preferably fascines of brush, which insures dry footing. Corrugated iron, when used, is laid up behind stakes or studding, anchored back at the top, but the principal use of this material is in roofs of splinter proofs, etc., being more nearly water proof than the usual roof of poles or boards.

Expanded metal and wire netting are used in a similar manner, but in loose soil canvas or empty sand bags must be placed behind them. Planks are either laid up on edge behind stakes, as described for corrugated iron, or on end, held in place by a waling piece at the top.

In permanent trenches concrete has been largely used. It is built in place, the trench wall being used for one side of the form, and is very effective, as

damage by shell fire is comparatively local in character.

EXAMPLE OF TRENCH CONSTRUCTION

Trenches Built by the 22nd N. Y. Engineers on the Mexican Border. These trenches, a half plan of which is shown in Fig. 90, were built not only as an engineering drill, but for the instruction of the infantry, and were used considerably by these organizations in their drills. It was not intended that they would serve as defensive works against a raid from across the Border. To obtain the maximum amount of instruction with the minimum construction, each section of parapet between traverses was finished in a different manner, showing a number of distinct forms of treatment, each designed for some particular condition.

In the remaining half of the general plan, not shown in Fig. 90, the fire trenches and machine gun emplacement only were constructed, as the communications and other works in rear would have been duplicates of those shown. There were thus a total of twelve squad trenches, two machine gun emplacements, two observation stations and the auxiliary works as shown.

The construction of this system of trenches was not begun with any particular plan in view. In fact, the order of construction followed very closely the procedure that would obtain under service conditions. The ground was almost level, and the grass tall, so a position was chosen at the military crest of a slight slope, and a line of plain traversed standing trench, with a low parapet, was first excavated. Then a passage trench was dug along the rear of the firing step, machine gun emplacements added, obstacles with automatic alarm signals placed in front, and the works in the rear commenced, embracing successively lat-

rines, shelter trenches, dressing stations, bomb proofs and cover trenches.

At A, on the left flank, was constructed a machine gun emplacement for all ground fire, similar to Fig. 30, p. 100. In rear of this was a splinter proof *niche,*

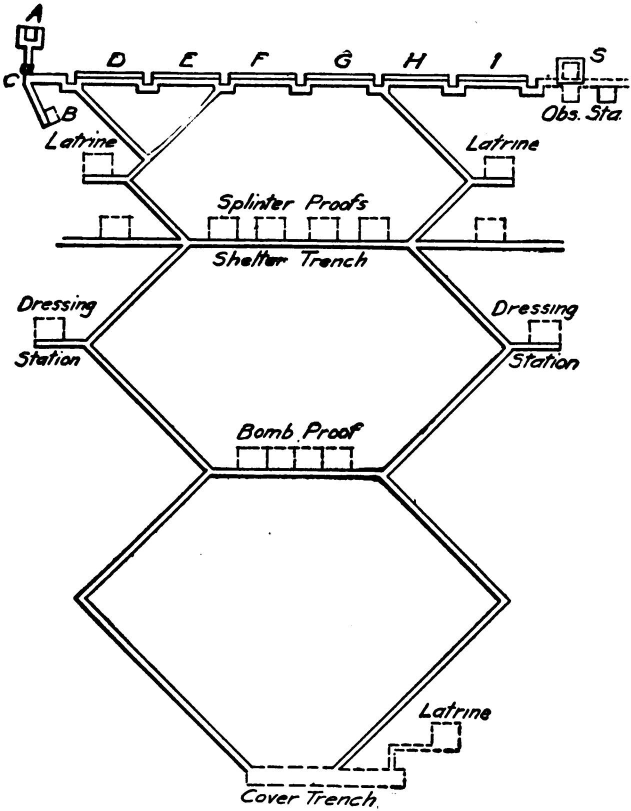


FIG. 90. TRENCHES BUILT BY NEW YORK ENGINEERS

B (Fig. 13, p. 85), with an *overhead traverse* (Fig. 37, p. 117) at C to protect from enfilade the trench leading to it.

The first squad trench, D, was constructed with an elbow rest (Fig. 91), firing step and passage trench. The second section, E, was similar, with the elbow rest omitted, resulting in a vertical face as in Fig. 21, p. 92. To show the cover provided by these two forms of trench, tapes were stretched from the crest

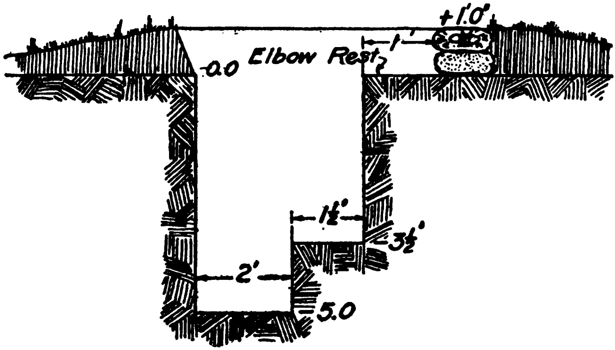


FIG. 91. FIRING TRENCH WITH ELBOW REST

of each parapet to the rear face, on the slope of the most effective shrapnel and long range rifle fire. The photographs, Figs. 92 and 93, were then taken of the trenches occupied by men in the firing position. That portion of each man above the tapes would be exposed to fire. An excellent idea of the comparative value of each type as regards cover afforded is thus obtained.

The section F was provided with notches upon the parapet, for directing rifle fire upon any particular object, as for instance the entanglements, at night.

The trench G was recessed as in Fig. 23, p. 94.

Section H was fitted with sortie steps. (Fig. 81, p. 208.)

The next squad trench, I, was given over to various types of revetment.

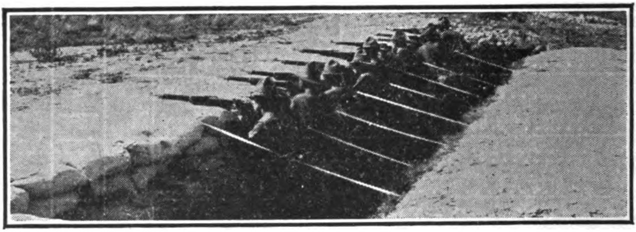


FIG. 92. COVER AFFORDED BY TRENCH WITH ELBOW REST

The six remaining sections, K to P, inclusive (not shown on Fig. 90), were constructed as follows:

K, trench with firing step and passageway, with

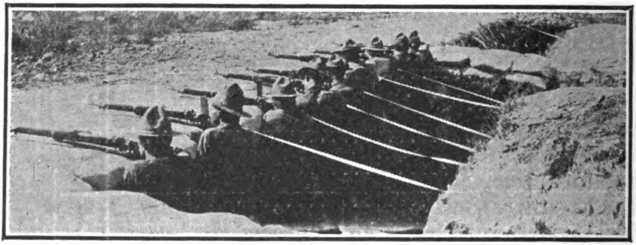


FIG. 93. COVER AFFORDED BY OMITTING ELBOW REST

embrasures or firing notches formed by sand bags on the parapet.

L, the same construction, but with sand bag *loop-holes* formed upon the parapet.

M, a firing trench of the same character, with *overhead cover* formed by a continuous parapet shelter built in the front wall of the trench. (Fig. 27, p. 97.)

N, a similar trench, but with the passageway built under the overhead cover. (Fig. 83, p. 210.)

O, a trench with overhead cover, a continuous loophole under the cover and provision for a second line in rear, firing over the cover. (Fig. 84, p. 211.)

P, a closed trench with hopper and steel plate loopholes, provided with concealing screens. (Fig. 86, p. 212, and Fig. 87, p. 213.)

On the extreme right flank, R, was built a machine gun emplacement for flank fire only, similar to that shown in Fig. 31, p. 101, but for one gun. A niche and an overhead traverse to protect the trench leading to it were constructed as at B and C.

In rear of the firing line communication trenches were built. At the first bend in each of these trenches was constructed a latrine under splinter proof cover. The *shelter trench,* about thirty yards in rear of the fire trenches, contained splinter proof shelters for the garrison of the latter and for the supports, to be occupied during a shrapnel bombardment. A look along this straight trench as built was sufficient to impress the lesson that a machine gun or a small group of riflemen established upon one flank could enfilade its entire length and hold the men in their shelters when their presence was urgently required in the fire trenches. A *self-defilading* trace, similar to that of the shelter trench in Fig. 76, p. 204, should have been adopted.

The communication trenches were continued to the rear, and at the first bend beyond the shelter trench were located the *dressing stations,* also of splinter proof construction. (Fig. 94.) A table, bench and shelf were the requisite furnishings, arranged as shown.

Further to the rear was the bomb proof, designed to accommodate the entire garrison of the trench during a bombardment by high explosive shell. The cover comprised six feet of earth, carried by two criss-crossed layers of 6″ x 6″ timbers. Owing to

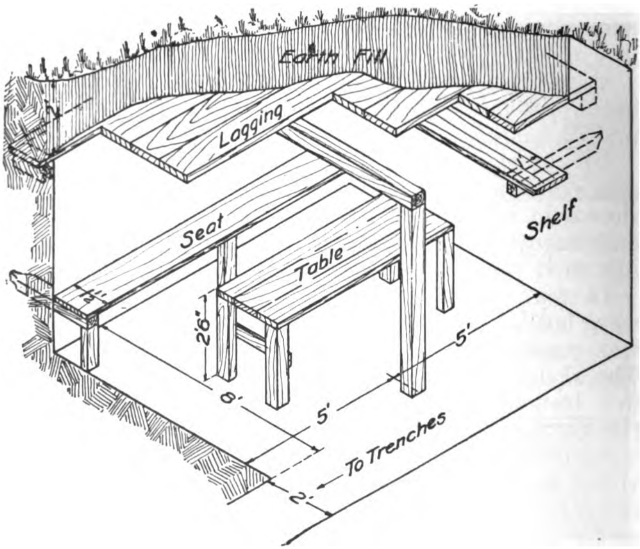


FIG. 94. DRESSING STATION

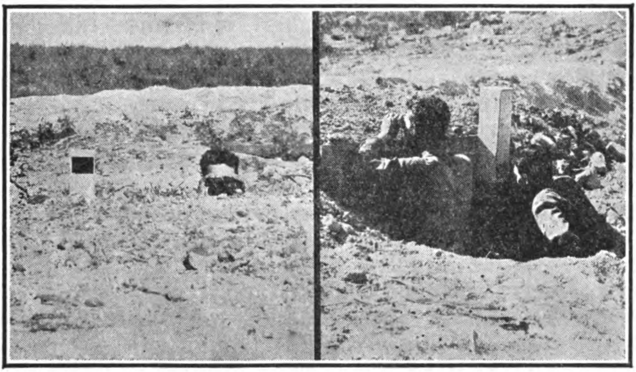
the shortage of lumber, this structure could not be completed as designed.

About 150 yards in rear of the fire trenches were the *cover trenches*. (Fig. 29, p. 99.) These trenches were for the housing of the troops in reserve, and in practice would contain latrines, facilities for sleeping and cooking, and would be designed for continuous occupancy.

Between the sections of the firing trenches, at S,

and reached by covered passages from these trenches, were the observation stations, open and covered. The former is shown in front and rear by Fig. 95. Note the trench periscope. The other station (not shown) was of the monitor type, with splinter proof overhead cover and narrow horizontal observation slots.

Successive Lines of Defense. The plan as shown,



Front. Rear.

FIG. 95. OPEN OBSERVATION STATION

with a depth from front to rear of 100 to 500 yards, depending upon the nature of the ground, would constitute the *first line*. The variations of arrangement are countless. We have seen that the shelter trench may be advanced nearly to the fire trench or consolidated with it. Dressing stations, latrines, bomb proofs, etc., may be connected by trenches parallel to the front, to facilitate lateral communication. These trenches may even be designed for frontal fire by the supports if the fire trenches are taken.

The "First line," therefore, consists of several

parallel rows of trenches, with one or more lines of resistance. It must be clearly understood, however, that these auxiliary lines are not to be considered as rallying points for troops driven from the fire trenches. These troops, if they have held their position until the last, are disorganized and beaten, and the enemy is usually following too closely upon their heels to permit their halting and reorganizing for another stand. The proper garrison for these trenches is the reserve, which, sheltered in the cover trenches, has not so far been engaged and is intact as to organization and practically so as to numbers.

Similarly, the second line and the third line, each developed substantially as explained for the first line, have their own garrison, and do not depend for defense upon such stragglers and fugitives as may drift back from a captured first line. Each line must successively stand or fall by its own efforts, and if after a stubborn resistance the position is carried, the opportunities for a concerted falling back to a previously prepared line are small indeed. On the contrary, the defeated troops usually face annihilation or capture.

SUPPORTING POINTS

In laying out a defensive line, there will be found certain points of greater natural strength than the general line, and therefore capable of a more stubborn defense and of more highly developed defensive works.

The natural strength of such points should be fully developed, to afford a more prolonged resistance, to break up attacks which may penetrate the line of trenches or to prevent the enemy's widening such a breach by rolling up the line from the flank.

It is obvious that the frontal fire from such a position can be of no greater volume nor more effec-

tive than from a line of trenches occupying the same front. The natural strength, therefore, cannot be completely developed, except perhaps passively, in the way of better protection to the defenders, unless the work be designed to hold out after the general line has broken and to check the spread of such a break. To accomplish this, facilities for all around fire must be provided.

Concealment in such a work is of vital importance, or at least sufficient disguising to give it the same appearance as the general line of trenches. Otherwise the position will be thoroughly demolished by a bombardment with high explosive shell before the attack. The enemy may not be willing to expend the shell to destroy a mere line of firing trench, but will most certainly do so upon the opportunity of eliminating a possible obstacle to his pushing home an attack.

Location. Supporting points may be located in rear of the first line of firing trench, with the intention of opposing a stubborn resistance to and breaking up an attack which has already passed the first line, or their front trenches may be a part of the general line and ordinarily perform the same service. In the latter case they are usually designated as *strong points,* are greater value in flanking adjacent lines, and their garrisons hold their portion of the front, instead of being immobilized in the rear, useless except for one emergency, which may never arise.

When opposing trenches are very close, however, as on the western front in Europe, where a sudden attack is liable to gain a foothold in the front line, and where a partial success must be prevented at all odds from spreading, the favored position appears to be in the rear. With the numbers of troops available, the garrisoning of these points does not drain the front line, and the works themselves, when so located, are removed from the danger of attack by mining.

Their concealment is also more easily effected than when a part of the first line. In such a location a supporting point is an emergency device purely, to be kept carefully under cover until the last moment, when it will suddenly burst into fire. Any form of construction or any activity which will tend to betray its position or its identity should be absolutely suppressed.

Trace. The trace may vary to suit the ground and the purposes for which the work is intended, provided that an all around defense is secured. A circular or elliptical trace is usually objectionable on account of the radial dispersion of fire. If the trace is formed of straight lines, the angles of junction should not be sharper than 120°, as the greatest angle from the perpendicular at which a rifleman can conveniently fire is 45° to the left and 15° to the right. If the interior angle, I, Fig. 96, at the intersection is less than 120°, there will be a dead angle of fire, d, at the exterior corner. However, if a machine gun is to occupy the corner, the angle may be made as sharp as desired.

On a hillside, the flanks may be groups of trenches in *echelon*, as in Fig. 15 (b), p. 86, faced nearly or fully to the front, thus avoiding a conspicuous diagonal trench cutting across the face of the slope, and at the same time preserving to these trenches their frontal fire, in addition to a considerable angle of fire to the flank. On the right this angle of fire to the flank is only about 15°, so these trenches may have to be faced more to the flank than on the left. The rear may be closed by a simple standing trench with a passageway, provided with splinter proof cover under the parados, i. e., on the side towards the enemy's artillery.

It has been argued by some authorities that the work should be left open in the rear, as it can then

be more easily rendered untenable to an enemy who may succeed in capturing it and who would otherwise find himself provided with the means of resisting a counter attack. These flank and rear trenches, however, are intended for use by the defense only in case the enemy breaks through the ad-

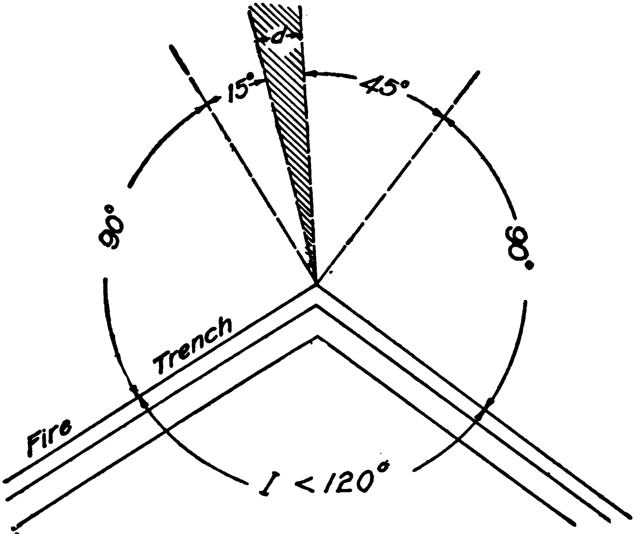


FIG. 96. DEAD ANGLE AT CORNER OF TRENCH.

joining line of trenches and partially or completely surrounds the supporting point. In such a case his own artillery can no longer fire, so these trenches will meet only an infantry attack. During the preliminary artillery bombardment they will be for the greater part unoccupied. If, therefore, the enemy should take the position, he will immediately be deluged with shrapnel from the defending artillery, and will be forced to withstand this fire in trenches not designed

to resist it. Even the splinter and bomb proofs, with their openings facing the rear, will afford him no protection. It must also be remembered that these same trenches which it is feared will enable him to hold the work against counter attacks may enable the original garrison to oppose a stouter resistance to his attack, and possibly prevent his ever obtaining a foothold from which he must be ejected. It is poor policy to design a defensive point with the expectation that it will fall into the hands of the enemy, and to purposely weaken it in order to facilitate its recapture.

Construction. The depth of a supporting point, as well as its front, should be such as to best fit the ground it occupies. As a general rule, the rear trench should be at such a distance from the front that artillery projectiles aimed at one will not endanger the other. The more accurate the fire, the less will be this distance, and if not accurate, then there will be little concentration and its effect will be considerably reduced. About fifty yards was formerly considered a safe distance, but with the improved accuracy of fire shown in the present war, it is believed that this may be reduced to thirty. The garrison, including supports, will usually be about one company to a battalion of infantry.

Obstacles about a supporting point should be continuous, and should be concealed in folds of the ground, in brush or tall grass, or in other ways rendered as inconspicuous as possible, in order not to betray the location of the position. They must at every point be under fire from the trenches. Entrances are preferably on the sides, to avoid enfilade by fire from the front, and should be covered. Interior communications should be ample and safe, since it may be necessary to shift the garrison to various points of the work under fire.

The general principles of trench construction apply

to the actual firing points. The trenches are not liable to be rushed, so that any additional protection which may be afforded by head or overhead cover is permissible if not opposed to good concealment. It has been recommended that head cover be provided by means of sand bags, kept filled in the trenches to avoid visibility, and placed upon the parapet by the defenders when firing is to commence.

Auxiliary Structures. Bomb proof cover, to resist heavy artillery fire, must be provided for the defense. In locating the bomb proofs, full advantage must be taken of all ground forms which tend to reduce construction, as more labor will be required upon this than upon any other feature of the work. Also, if located entirely in excavation, there will be a large amount of earth to waste, all of which must be placed where it is not visible to the enemy. To minimize the consequences of a chance hit by a large shell, bomb proof cover may be distributed among several shelters.

Machine gun emplacements should be built at all points from which their fire may sweep the adjoining trenches, the entanglements, or the front and flanks of the supporting point itself. They are preferably of the type for flank fire only, and provided with overhead cover, if this can be made inconspicuous. The guns will be moved from one emplacement to the other to meet varying phases of the fire fight.

Observation stations will be located at favorable points, concealed by vegetation, and provided with hidden communications. They should be inside the obstacles, and may be occupied in turn as the action can thus be brought under better observation. Finally, the commanding officer is provided with a station, equipped with overhead cover and so located as to permit as complete a view as possible of the

entire terrain controlled by the work. He must watch his own front and flanks, neighboring trenches and obstacles, and the enemy's front, in order that he may dispose his garrison and machine guns to the best advantage to meet conditions as they arise.

XV.

WIRE ENTANGLEMENTS.

By common consent the high wire entanglement has become the standard military obstacle. It has been highly developed on the western front in Europe, and a number of notes upon its use under service conditions are now available.

The principal developments have been along the line of simplifying the construction and in the use of artillery fire to open a passage for the attacking troops. It was known formerly that a direct hit by high explosive shell would cut the wires in its path, but it was not considered that artillery fire in general would have much of an effect upon entanglements. This view was influenced by the belief that such shell would never be available in sufficient quantities to permit its use for the destruction of wire entanglements. The development, therefore, lies more in the quantities of shell which it is considered advisable to expend for this purpose than in the discovery of the effect of such fire.

General Principles Governing Location. As a general rule, the outer edge of an entanglement should not be near enough to the trench which it protects to allow the throwing of hand grenades into the latter. At the same time, the distance must not be too great for adequate watching or guarding by the defense. Furthermore, it must not be so great that the enemy may approach and cut through it while the trench is under their artillery fire. These restrictions usually fix the distance at from fifty to one hundred yards. It is better, however, to make this distance

irregular, so that the entanglement will not be parallel to the trace of the trench. This will lessen the liability of the trenches being discovered through the position of the obstacle, and will prevent hostile artillery from using the latter in ranging their fire upon the trench.

The wire available should be so disposed as to form a deep rather than a dense obstacle. The time of cutting through is thus increased, and a greater amount of shells will be required for its destruction by artillery fire. The depth should not be less than thirty feet.

A double line, separated by an open space, is considered advisable as offering to the artillery a target of greater dispersion, and as tending to stiffen the defense. A determined attack upon an entanglement is certain to affect the morale of defending troops. As the barrier between them and the enemy is gradually cut away, their fire becomes less and less effective, and the tendency is strong to evacuate the trenches before the enemy can come to grips. If a second obstacle, even a single fence, will still be interposed after the main entanglement is cut through, the defenders will be steadier and fire with better effect, which should prevent the attack's ever reaching the second barrier.

Types. Most of the entanglements placed on the western front in Europe are constructed at night, in the face of the enemy, and great care must be exercised not to draw his fire upon the working parties by undue noise. At the same time, the construction must follow simple forms, in order that the operations may proceed in the dark without confusion. The form shown in Fig. 33, p. 109, although a very effective obstacle, is not suitable in such a case, on account of the noise of driving its posts and of its complicated wiring. The approved types follow the

plans of Figs. 97 and 98, comprising as few long posts as possible, supporting a structure consisting mainly of longitudinal wires. Fig. 97 is a simple wire fence, with a front and rear apron. The complete obstacle consists of two or more of these units, separated by open spaces. Fig. 98 is a double fence, with front and rear aprons,

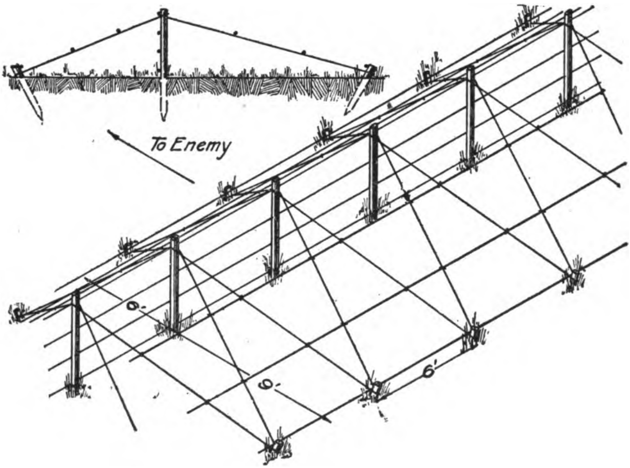


FIG. 97. DOUBLE APRON ENTANGLEMENT.

cross wired between. This might well form the principal obstacle, with the addition of a strong fence in rear. Fig. 97 requires, per yard of front, for a double line, 34 yards of wire, and Fig. 98, with a guyed fence in rear, requires 38 yards. It has been estimated that for the complete wiring of a mile of front, 1st, 2nd and 3rd lines, with supporting points and all auxiliaries, there will be required about 900 miles of wire.

For the rapid construction of such entanglements,

the materials are assembled in the rear and regular drills are held in which each man learns thoroughly the duties which he is to perform. The materials are as follows:

Wire. The quantity of wire required is so great that it must be obtained from all possible sources and will be of all possible types. A special wire

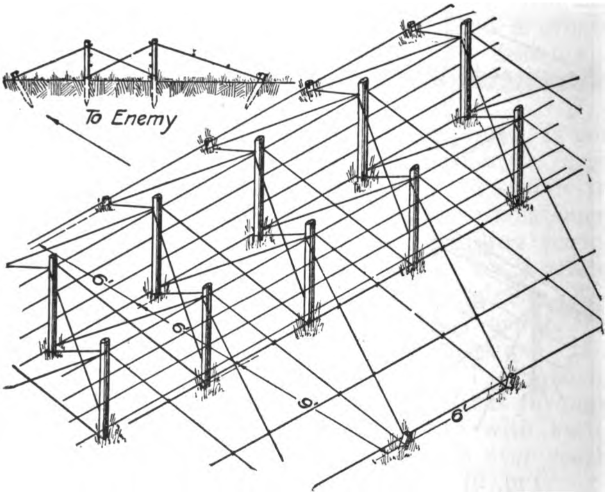


FIG. 98. DOUBLE FENCE ENTANGLEMENT.

(Fig. 99), containing four one-inch prongs to the inch, has been used in large quantities, but commercial barbed wire is usually much easier to procure, and even this may be so scarce as to require the use of any available wire. Where both are to be used in one entanglement, the smooth wire is used for stays and tie wires, the barbed for longitudinals. A reel of wire is prepared for use by loosening and unwinding the end for one turn, wrapping the coil with

canvas, and rewinding the loose end over this, so that it may be found in the dark.

Standards or Posts. If of wood these must be of considerable strength, and therefore difficult to set. The standards in most common use are of two kinds, angle irons, with notches to hold the wire, and a

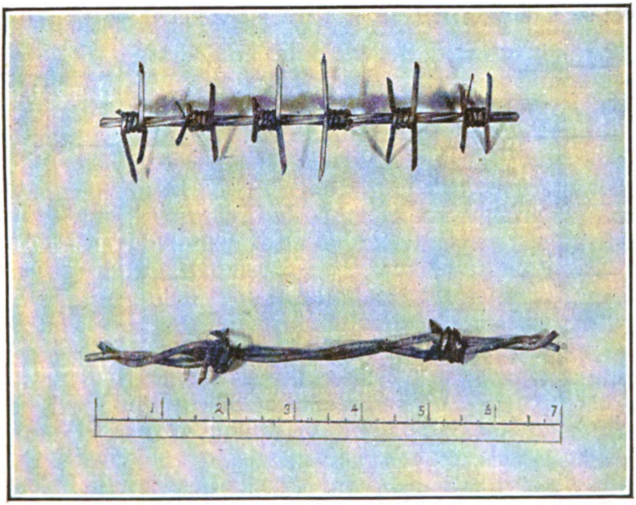


FIG. 99. SPECIAL ENTANGLEMENT WIRE.

specially prepared type of iron post, with three or four eyes and a screw end, so that it may be screwed into the ground. (Fig. 100.) The *pickets,* for holding trip wires and the lower ends of the stays, are about fifteen inches long, with one eye at the top. Angle iron posts and pickets are driven by mauls whose heads are muffled by eight to ten thicknesses of sand bag.

The wire is attached by (a) looping it over the posts and through the open eyes, (b) simply laying it in the eyes, (c) laying it loosely in the eyes and giving the post a twist after all wires are in place, or (d) laying the wires in the eyes and securing them by separate binding wires. Method (c) is not applicable to angle iron posts. Method (b) is objectionable because a single cut in a wire slackens it throughout

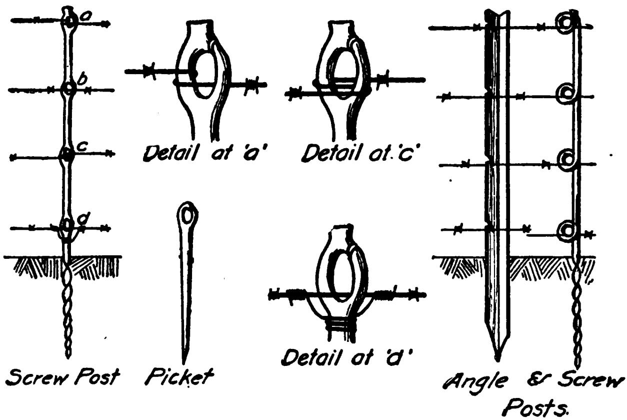


FIG. 100. SPECIAL ENTANGLEMENT POSTS.

its length. The eyes, or some form of notch, are essential, as otherwise the entanglement might be flattened by slipping the wires down the posts to the ground. With wooden posts the notches must be cut beforehand, or the wire fastened with staples, the driving of which would certainly draw the enemy's fire.

In preparing to erect entanglements at night, the posts are made up into bundles of a convenient size to carry, wrapped in sand bags and tied firmly with

wire, to prevent their rattling. The pickets are usually carried in sand bags, similar precautions being taken against noise.

Construction. Having been prepared by drills in the rear, until each man knows exactly his duties, the working party proceeds to the front with the material, locates itself on the ground, and works rapidly and noiselessly. Each party constructs a length of about fifty yards, and gaps are left between the units for patrols, counter attacks, etc. These openings are *zig-zag* or diagonal to the front, so that they are not apparent to the enemy. In defense they are swept by specially designated machine guns. Their location is concealed from the enemy, not alone to prevent his entrance thereby, but to avoid his making similar dispositions to sweep them by machine gun fire during a sortie by the defense.

The line upon which posts are to be driven may be laid out on the ground by tape, spaced off by pieces of cloth knotted into it, but usually such refinement is unnecessary. In fact, the more irregular the plan and profile of an entanglement, the more difficult it is to penetrate. The distance from the trench may be fixed by pacing, and an electric flash, shaded from the enemy, provides a ranging point towards which the men distributing the posts may work. The side posts and pickets are placed by estimation, opposite the intervals in the center line of posts and at *about* the desired distance from them.

The following is a specimen drill for the construction of an entanglement of the type shown in Fig. 97. The working party consists of twelve men, Nos. 1 to 6, front and rear rank, with the necessary non-commissioned officers. The men wrap their legs, waists and forearms with several thicknesses of sand bags, and wear heavy gloves, which may be padded

or studded with rivets. The work is divided into three successive *duties* for each man.

FIRST DUTY.

No. 1. Lay out posts along line.
No. 2. Front rank—assists No. 1.
Rear rank—holds posts for No. 3 to screw in.
No. 3. Separately—screw in posts.
No. 4. Lay out front and rear pickets on line.
No. 5. Screw in front line of pickets.
No. 6. Screw in rear line of pickets.

SECOND DUTY.

No. 1. Lower wire of fence.
No. 2. Second wire of fence.
No. 3. Third wire of fence.
No. 4. Top wire of fence.
No. 5. Erect stays to front pickets.
No. 6. Erect stays to rear pickets.

THIRD DUTY.

No. 1. Top wire on front apron.
No. 2. Second wire on front apron.
No. 3. Lower wire on front apron.
No. 4. Top wire on rear apron.
No. 5. Second wire on rear apron.
No. 6. Lower wire on rear apron.

The end posts of a unit are stayed longitudinally, these stays being placed by the men who string the top wire on the posts. The front and rear stays are given a kink where the apron wires rest upon them, to prevent the latter's slipping down. The joint is made fast by binders of plain wire.

Portable Entanglements. The necessity of rapid and noiseless construction has led to the performance

of as much of the work as possible in rear of the line, and has resulted in the adoption of several portable entanglements. Of these there are two principal types, first, those whose frames are constructed in the rear, carried out in front and wired in position, and second, those which are built in complete units, wire and all, and placed in position in front of the trenches. In the former type, the frames, pyramidal, X, or star shaped, simply take the place of posts, and thus avoid the noise of driving. The latter type is used to blockade roads, to quickly provide an obstacle in front of a newly captured position and where construction operations in place are not possible. They may take a number of forms, of which the *wire chevaux de frise* and the *French spiral* or *French wire* are in most common use. The former consists of a number of X-frames attached to a longitudinal axis and the whole covered with barbed wire. Its efficiency as an obstacle is not effected by upsetting it or rolling it over. The latter consists of a double coil of wire, wound in opposite directions, and fastened together at a number of points upon their circumferences. The spiral is collapsed for transporting, and the ends pulled apart to place it. A double spiral, about four feet in diameter, is thus formed, which is pegged to the ground at several points. It is said to resist artillery fire very successfully.

Protection of Entanglements. Entanglements once placed must be carefully guarded against night attacks. This is done by *automatic signals*, *illuminating devices* and *advanced sentry posts.* The first two may be combined in the *flare,* of which there are a number of types displaying considerable ingenuity in their construction.

Flare. An automatic flare of a type in general use by the British in France is shown in Fig. 101. The

standard is hinged to a stout post, and normally lies horizontally in a shallow trench. When the supporting prop is removed by a pull on the *trip-wire* the weighted end drops into the pit, pivoting about the hinge, and raising the other end four or five feet above the ground surface. This end carries a flare, similar to a *Coston Signal,* behind which is a tin re-

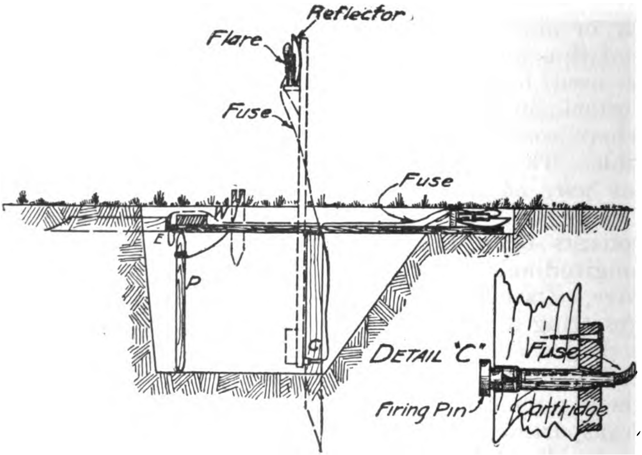


FIG. 101. AUTOMATIC FLARE.

flector to shade the defenders' trenches. The flare is ignited by an instantaneous fuse, inserted in a cartridge shell C, the firing pin of which is struck by the falling weight W.

Or, the fuse may be ignited by a *Bickford fuse lighter,* which is a pasteboard tube containing a friction primer. One end is open for the insertion of the fuse, the other contains a wire loop, the forcible withdrawal of which ignites the primer. This is attached at E, Fig. 101, so that the falling weight, W,

draws out the wire and lights the instantaneous fuse leading to the flare.

As the enemy may carefully cut all trip wires as encountered, the signal is sometimes arranged to trip either upon a pull or a slackening of the actuating wire. This is done by means of a second cord attached to the prop P, Fig. 101, leading away from the trip wire, over a small pulley in the side of the pit, and carrying a weight. This weight is supported, and the prop thus kept in position, by the tension in the trip wire, which, when cut, will allow the weight to drop, withdrawing the prop as before. A pull on the alarm wire lifts the weight sufficiently to displace the prop towards the pull.

These flares burn with an intense light for about one minute, which is usually sufficient time to break up a wire cutting party. The alarm once given, however, the illumination may be continued by firing *star shells* from extemporized gas pipe mortars. These shells, upon bursting, release a burning ball of powder, supported by a small parachute, which drifts with the wind and lights up the ground below for about a minute.

Advanced Sentry Posts. Such posts are a development of the night sentry posts shown in Fig. 14, p. 86. They are carried up into the midst of the entanglements, are provided with overhead cover if consistent with concealment and a clear field of view, and may accommodate several men. They are protected from the fire of their own lines, and provided with telephones or other reliable means of communication. In some cases, the occupants, after giving the alarm of an attack, rejoin their own forces, closing the passage after them. In others they retreat into their dugouts and lie hidden during the attack.

The functions of these posts are three fold. They watch the entanglements and give warning of an at-

tack, they listen for sounds of the enemy's subterranean mines and, provided they possess good cover, they are capable of strong resistance and may delay an attack while the main defense is organizing to receive it.

For directing night fire upon any previously designated objective, the simplest comprises a couple of

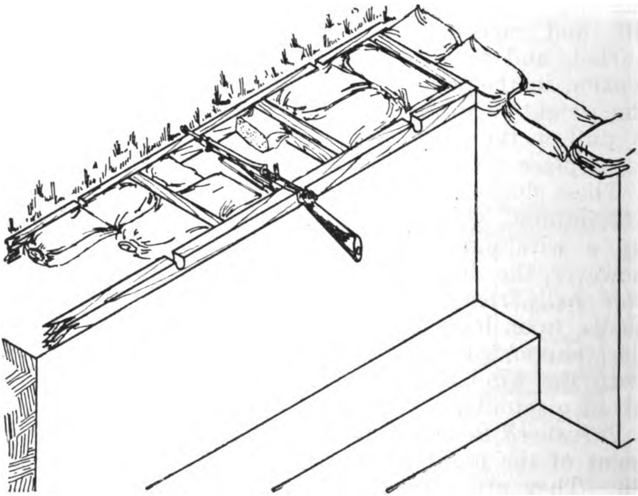


FIG. 102. GUIDES FOR NIGHT FIRING.

notched boards placed upon the parapet. (Fig. 102.) The front board is first set in place and nailed to stakes. Then the rear board is set with the rifle laid across both boards so as to secure the proper elevation. The rifle is then carefully aimed at the objective and the notches marked. When these are cut to the same depth in both boards, the rifle, placed in the notches, will have the desired direction and elevation.

CHAPTER XVI.

ORGANIZATION OF CAPTURED POSITIONS.

An attack upon the western front in Europe depends largely upon the Engineers to make the necessary preparations and to assist in holding positions that may be carried by assault.

PRELIMINARY WORK.

Before the exact point of attack can be fixed there must be reconnaissance, both from the air and from advanced points. Observation from the latter is also very essential to an intelligent direction of the artillery fire which prepares the way for the infantry assault.

Sapping.

The construction of advanced observing posts, and of covered approaches leading out to them, follows the methods of *sapping*, as given in Chapter X.

The stations themselves are usually built under the cover of some feature which has been in existence for some time and to the sight of which the enemy has become accustomed, such as a ruined building, a hedge, clump of brush, etc.

The cover is made as strong as possible consistent with clear observation and concealment from the enemy, and every care is taken to prevent betrayal of the position by the approaches leading to it.

In driving the sap, therefore, it is customary to carry all earth to the rear, as it would be very conspicuous if thrown up, as in Fig. 37, p. 117. The

important points to conceal are the point of departure of the sap from the trench and the sap head while work is in progress. At night a section of the trench parapet may be removed and a layer of plank placed flat upon the ground for the entire width of the parapet, which is then rebuilt upon the planks. The sap is now started by tunnelling under these boards, and proceeds by full depth excavation, undermining the earth ahead and letting it drop into the sap.

Progress is naturally slow, as only one man at a time can work in the sap head. From 1½ to 2 feet per hour is a very good rate.

Saps are continually being driven out towards the enemy, to listening posts, to advanced posts for the protection of obstacles, and in the process of advancing a section of the firing line to a better position.

In many cases concealment is impossible, and artificial cover, such as sandbags and steel shields (Fig. 88, p. 215), is freely used to protect the working parties. Much of the work is necessarily done at night, and a long sap may be rapidly constructed by placing men in pairs on the line at intervals of 20 to 30 feet. The men in these pairs first excavate a narrow trench, just long enough to permit the free use of their entrenching tools. When a sufficient depth is attained, they begin to work away from one another, towards the next pit. This work of connecting the line of pits may continue after daybreak.

Mining.

An attack stands a much better chance of succeeding if the enemy is thrown into confusion just previous to the assault by the explosion of a mine under his works.

Mining proceeds as oulined in Chapter X, the work being usually done by special Engineer troops, re-

cruited from men who have followed mining as a profession in civil life.

Mine galleries on the British front are customarily of a trapezoidal section, 4 feet high, 2½ feet wide at the top and 3 feet at the bottom. They are usually full timbered throughout. The excavated earth is most silently removed by placing it in sandbags and hauling it out. To accomplish this a continuous rope should be used, reeved through blocks in the heading and around the drum of a winch at the entrance of the gallery. Otherwise it would be necessary to constantly carry the end of the rope back into the heading.

The sand bags, instead of being emptied, are used in the trenches, in accordance with the maxim of efficiency—"When sand bags are to be filled, look for the nearest excavation in progress, and fill them there." In average soil, the rate of progress is ½ to 1 foot per hour, necessitating the removal of 12 to 24 sandbags in this time.

Mine galleries have been successfully driven to a length of nearly 150 yards, requiring several weeks to complete them. It is reported that in the recent British offensive at Ypres, in Belgium, mines were fired which had been completed a year previously, and held awaiting a favorable opportunity for use.

Charges vary greatly. It is said that as much as 6½ tons of explosive has been fired in one charge, resulting n a crater 60 yards by 40 yards. *Camouflets,* directed against the enemy's underground works, have been fired at considerable depths with charges of 2 to 3 tons without breaking through the ground surface.

A machine has been invented for rapidly drilling and charging a small mine, which will probably have considerable use in countermining. It is claimed that a horizontal hole can be drilled for 1000 feet at a

rate of two feet per minute, a chamber enlarged at the outer end, charged with 1200 pounds of explosive, and the charge exploded electrically.

Preparations for the Assault.

Passage through Obstacles. Such passages should be left when constructing the obstacles, but in case this has been neglected or there is need of amplifying them, the work is done on the night preceding the assault.

The openings are zig-zag or diagonal to the front so as not to be apparent to the enemy, and in defense are swept by machine gun fire or closed by portable obstacles.

Sometimes wide saps are driven under the entanglements for the passage of an attacking force.

Parallel d'Attaque. The French make use of a device called a *parallel de depart* or *parallel d'attaque,* which is a trench parallel to the general line and lying in *front* of their own obstacles. This trench is prepared the night before the attack by troops who will not take part in the latter, and is arranged with steps in its front face, so as to facilitate a quick exit. It communicates with the front line trench by saps or tunnels.

The principal objection to such a device, outside the labor necessary to construct it and the liability of interference by the enemy during its construction, is that after an unsuccessful attack it may be occupied by the enemy's counter attack and held as a thorn in the side of the defense.

Preparation of Materials. Engineers always accompany an attack and assist in the organization of captured points. They should therefore be provided with tools and explosives, revetting materials, particularly sand bags, and wire.

If the attack is to be made from the trenches,

ladders must be provided, at the rate of about one to each fire bay. When a mine is to be exploded and the crater occupied, all trenches will be in loose earth and must be revetted. Special braced frames of wood are usually made up and carried along, to strut these trenches.

ORGANIZATION AFTER CAPTURE.

Trenches.

Upon the capture of a system of trenches the work of organizing for defense immediately commences, for every possible effort will be made by vigorous counter attacks on the part of the enemy to recover the lost ground. This organization proceeds by well-defined steps:

1. The conversion of a group of trenches into a *strong point*, by:

(a) Throwing over the parapet towards the enemy and constructing a new firing step. This may require digging the step out of the original rear wall of the trench and using the excavated earth for a parapet.

(b) Isolating the position from the remaining trenches held by the enemy by encircling it with a line of wire entanglements, made double and as strong as time will permit.

(c) The construction of new trenches if necessary, to secure fire to the flanks and preparation for practically an all around defense.

If the captured system of trenches is extensive, it will be converted into a number of such strong points, so arranged as to support one another. These may later be connected by lateral communications so as to provide a continuous front line.

2. The connection of these points with the rear by adequate communicating trenches, in order that sup-

plies and fresh troops may be brought up and the wounded sent to the rear.

3: The filling in of all unused trenches within forty or fifty yards to prevent the enemy's bombers from stealing up under cover and bombarding the captured trenches with grenades.

4. The construction of supporting points in rear of the line of strong points, preferably opposite the intervals between the latter.

At present, quite accurate maps of the enemy's trenches are made from photographs taken by aerial observers, so it is usually possible to formulate a plan of action and assign specific duties to the engineer troops before the attack in order that their execution may proceed without confusion. The whole aim of the defensive works at the beginning is to place the captured trenches in a state to meet the first counter attacks. The occupying troops must expect to be practically isolated and to maintain their position against all attacks until dark.

Fig. 103 shows the consolidation of a system of captured trenches into a strong point.

Villages.

The defense of a village is also planned from maps made before the attack. It comprises the construction of a *keep,* or strong point, centrally located and capable of all around defense, and various centers of resistance on or near the main approaches, connected to the keep and to each other by covered or concealed communications. The vicinity of prominent buildings should be avoided in locating these works, as they offer a conspicuous mark for artillery.

Cellars are made into bomb proofs by covering the floors above them with earth or sand bags of gravel, etc. Those which command a road may be made into masked machine gun emplacements.

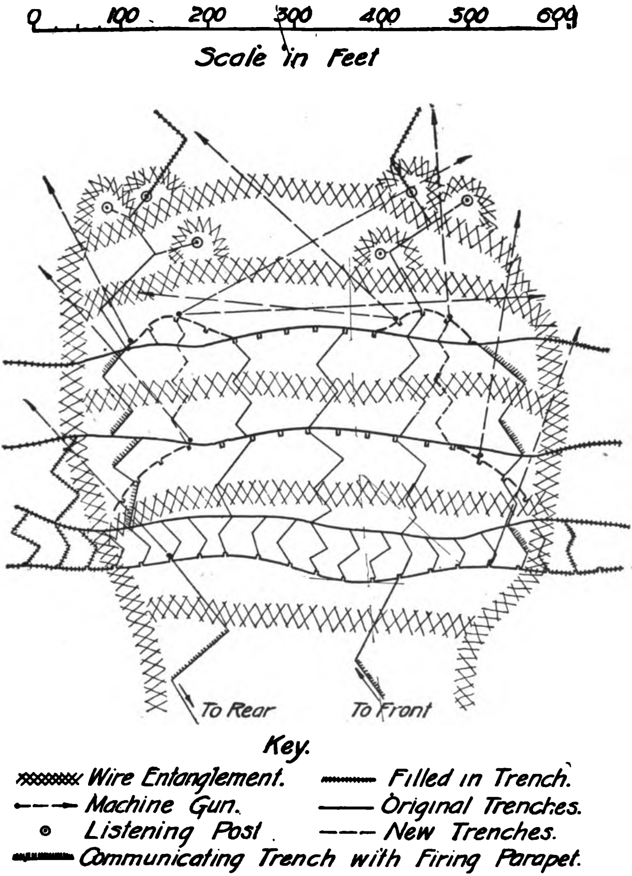


FIG. 103. CONSOLIDATION OF CAPTURED TRENCHES

The first step in organizing the defense is the closing of all entrances to the village.

Second, establish the centers of resistance to defend these.

Third, construct the keep.

Fourth, construct communications from keep to rear and to outlying centers of resistance.

Fifth, adapt cellars as above.

Sixth, connect centers of resistance by lateral communications.

Woods.

The best position for a defensive line through a wood is just far enough inside to permit a clear view into the open. If there is a hedge at the border of the wood, it may be thinned so as not to interfere with the view and interlaced with wire to form an obstacle.

Similarly, thick underbrush may be thinned out and wire strung between trees. If time permits the edge of the wood may be serrated by cutting, and the clumps wired, causing the attackers to bunch in the open spaces, where they make good targets for machine guns. Within the wood centers of resistance are constructed and radiating lanes cleared for machine gun fire. Deflecting obstacles are placed to force the enemy into these lanes.

Mine Craters.

In Enemy's Line. Such a crater usually results from a mine fired under the enemy's trenches, and is expected by the attackers, who have troops in readiness to seize the crater. In this case the front lip is occupied. Fig. 104.

The front of the crater is wired and several squad trenches are constructed in the lip, just behind the crest. Lateral communication is secured by a trench

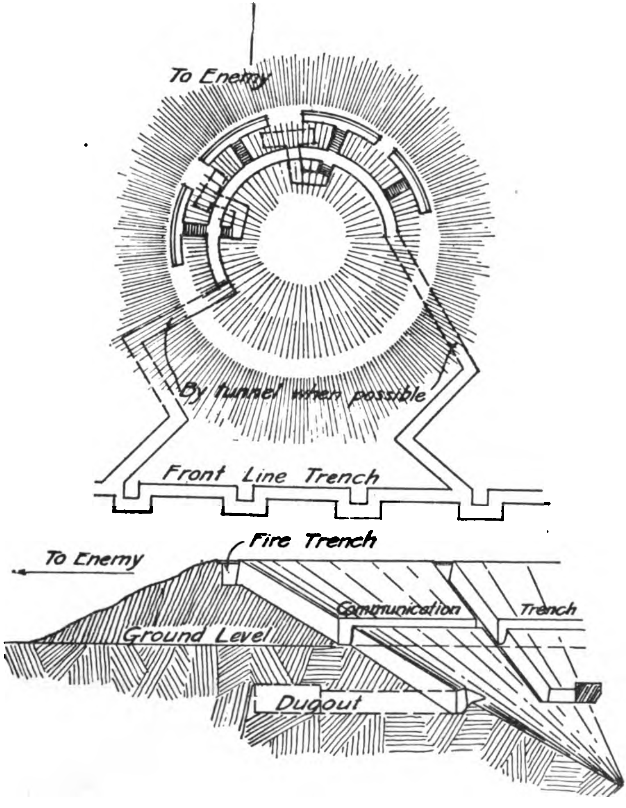


FIG. 104. OCCUPATION OF FRONT LIP OF MINE CRATER.

around the inside partially down the slope from which dugouts are built into the wall of the crater. All trenches should be provided with a parados to protect the occupants from reverse fire.

As in the consolidation of trenches, all those within

bombing distance should be filled in. Communication to the rear is secured through trenches passing *through* the walls of the crater, for safety and for conceal-

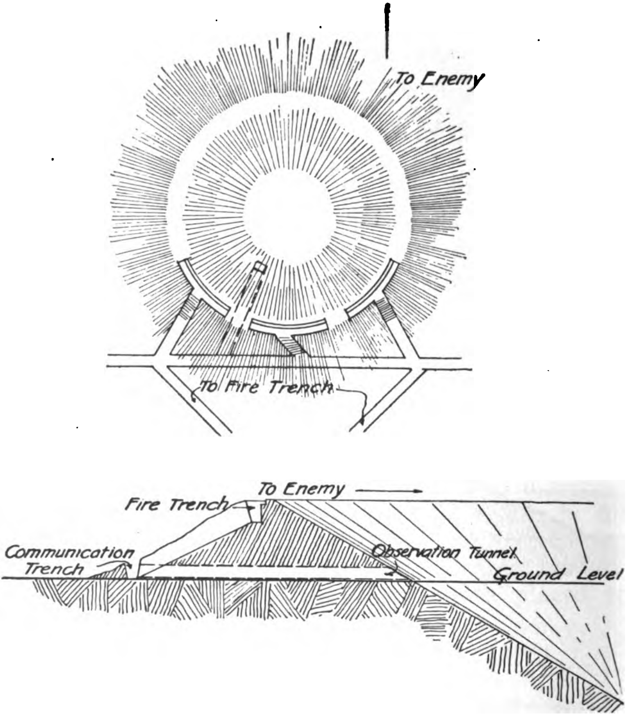


FIG. 105. OCCUPATION OF REAR LIP OF MINE CRATER.

ment. These should be at the sides, to avoid enfilade, and there should be at least two, in case one is closed by falling earth.

In Defending Line. Upon the enemy's exploding a mine under our lines, or our firing a countermine

close in front, the rear lip of the crater should be occupied.

Several squad trenches are then constructed just in rear of the lip, the crater is filled with wire and portable obstacles, and tunnels are driven through the rear lip to bombing and observation stations inside. Fig. 105.

When the lip of a crater or a chain of craters furnishes no field of fire to the defense, it is made into an obstacle by filling the inside with portable wire obstacles and installing bombing posts upon the rear lip. At all costs, the enemy should be prevented from seizing the crater, or approaching under its cover.

Communicating trenches lead to these bombing posts, and wire is placed to the front and sides of these approaches at such a distance as to keep the enemy's bombers out of range.

CHAPTER XVII.

ENGINEERS IN FIELD SERVICE.

In Chapter VI is given a complete list of the duties with which Engineer troops are charged. At the end of the list is the following:

"The services in the above list are executed under the supervision of engineer officers by *engineer troops*, by *details from other troops*, by *civilian labor* or by *any combination of these means* as the particular circumstances may require."

EXPERIENCE IN MODERN CAMPAIGNS.

The U. S. military observer with the Japanese army in the Russo-Japanese War stated that the duties actually performed by the Japanese engineers were limited to bridge building, road construction, building redoubts (strong points or supporting points) and demolitions and that they were kept busy by these duties.

The observer with the Russian army reported that the Russian engineers were fully occupied by:

1. Ponton work.
2. Sapping and mining.
3. A limited amount of pioneer work.
4. Directing the labor of civilians and other troops in entrenching, construction of obstacles, road and bridge work, railroad repair and all emergency work.

A paper upon the duties of engineer troops, by Capt. Burgess, Corps of Engineers, U. S. Army, published in 1908, states:

"The best the engineers can do is to accomplish first the essential work, then to perform as rapidly as

possible the other important works in the order of their importance."

A recent British writer, dwelling upon the work of the Royal Engineers, says that in the beginning of the war demands for the services of the Engineers were prohibitive, and have resulted in the taking over of a large amount of engineering work by the Infantry, leaving to the Engineers the following duties, exclusive of mining, railways, etc., which are in charge of special troops:

1. The construction of special points, requiring great technical skill, as:

   (a) Bomb proof machine gun emplacements.
   (b) Deep shell proof dugouts or cave shelters.
   (c) Strong points in the first line.
   (d) Supporting points or *Points d'Appui* in the rear.

2. Training the Infantry in the simpler branches of engineering work.

3. The collection of engineer material.

The two latter are the most important.

PROBABLE FIELD DUTIES IN U. S. SERVICE.

From the foregoing it appears that Engineers in the field will not be able actually to execute all the numerous duties outlined in Chapter VI. In fact, as expressed by one authority, they will perform only such duties as require technical skill or equipment not in possession of other troops.

Topographical work will be done, depending upon the country, the nature of the campaign, and the sufficiency of existing maps. This work, with photography and map reproduction, will be done by small details of especially qualified men, and will not affect the majority of the Engineers.

Fortification and siege work will usually be exe-

cuted by the infantry which will occupy the completed entrenchments. The siting of these works will be done with the assistance of an engineer officer, and engineers may supervise the construction, but with the exception of points requiring special preparation, the infantry will supply the labor, using tools from the Engineer Train. With an army immobilized in trenches, and no pioneering to be done for moving troops, the Engineers would be largely used in improving and maintaining trenches, constructing obstacles, etc.

Demolitions, especially those requiring explosives, will be done by the Engineers, as requiring technical training not given to other troops.

Battlefield illumination will, with mining and railway work, be performed by special engineer troops, especially trained and equipped for this work.

General construction will be delegated to civilian labor or to special troops, unless in the nature of emergency work at the front.

In the *service of communications,* or *pioneer work,* the Engineers will find their true field of action. Probably 75% of their work will pertain to roads or bridges or to emergency work upon railways at the front and outside the sphere of action of the railway troops along the line of communications.

To summarize, then, the Engineers in campaign will occupy themselves mainly with pioneer work, demolitions, topography, and, a matter of which the importance is scarcely realized, the supply of engineer tools and material, all of which are carried in greatly inadequate quantities for the performance of extensive work.

The British writer before mentioned emphasizes this by quoting the amounts of material used in one mile of front, 1st, 2nd and 3rd lines, with all communications, as follows:

Wire: 1,600,000 yards, or 900 miles; weight 110 tons.

Posts: 12,000.

Pickets: 12,000.

Sand bags: 6,250,000; weight 1,000 tons.

Corrugated iron: 36,000 running feet.

Timber, average 3″ x 3″: 1,125,000 linear feet.

All this is in addition to the revetting materials required, as planks, wire netting, expanded metal, etc.

An engineer regiment of a thousand men would require 8 months to fill and place the sand bags alone. In one division, holding two or more miles of front, there are carried only 7,500 sand bags, 4,500 in the Engineer Train and 3,000 in the company tool wagons.

Furthermore, in one wagon of the Engineer Train, intended for the use of a regiment of infantry, 2,002 enlisted men, there are only 450 excavating tools (shovels and picks), an average of one to about five men. If working in two reliefs there would still be less than one tool to two men.

It is stated that the shortage of tools among the British troops at the beginning of the war was a great handicap, and that the surrounding country was continually being scoured for shovels, etc.

The duties of the 22nd N. Y. Engineers on the Mexican Border, as divisional engineer troops, were largely confined to pioneer and topographical work. A considerable amount of fortification and other work was done for drill and instruction purposes, but the duties performed in response to calls from Division Headquarters were practically all of the former character.

Topography.

This is usually done by the methods of road sketching, using the engineer sketching board, as described

in Chapter XIII. These road sketches may cover quite a long distance with sufficient accuracy for military purposes. When troops are assembled for extended periods in camp, however, the engineers are usually called upon for a complete map of the surrounding country. In assembling field sketches to make such a map, the lack of some system of control becomes very evident.

At Camp Whitman, N. Y., the Engineers made a maneuver map of the surrounding country, covering about 64 square miles. The control in this case was a skeleton of roads, enlarged by co-ordinates from the U. S. Geological Survey Map.

Control by Automobile Traverse. On the Border, however, these maps were incomplete, numbers of new roads having been opened since they were made. The area to be covered was about 200 square miles, extending for 36 miles along the Rio Grande, this being the sector covered by the N. Y. Division.

The use of an automobile traverse for control was decided upon after it had been successfully tried for mapping a new stretch of road about 15 miles in length. A prismatic compass was used for direction and the speedometer for distance. The latter, graduated to tenths of a mile, could easily be read to quarter-tenths, which, on a scale of 3 inches to one mile, is about a sixteenth of an inch. Moreover, the error of reading is not cumulative. A circuit of 35 miles by this method was closed within a tenth of a mile, and another of 21 miles within half this amount.

Furthermore, as the work developed, and the possibilities of the plan became apparent, the notes were made very complete, as in Fig. 106, so that they could form the basis of a complete road map.

Such a traverse could be made at a rate of 10 to 12 miles per hour, and on one day 80 miles were

completed. Most of the notes were taken while under way, but a stop could always be made if the sketching got behind. A majority of the roads were straight and through wild country, necessitating fewer notes than shown in Fig. 106. The notes were legible to

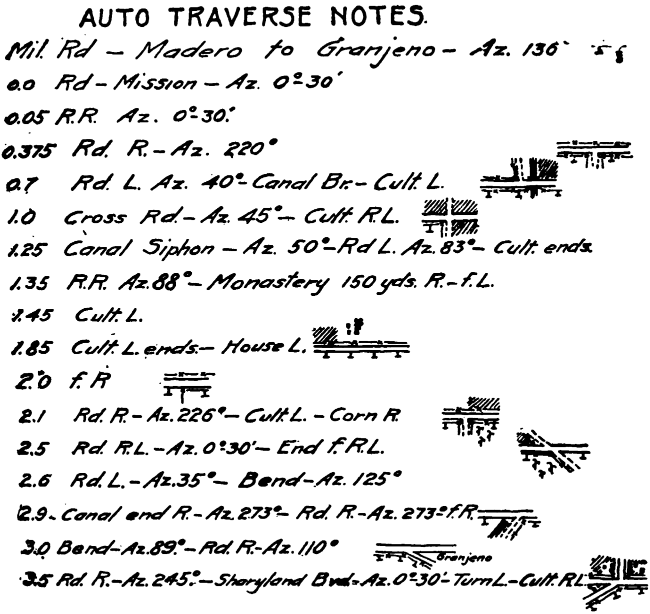


FIG. 106. AUTOMOBILE TRAVERSE NOTES

the person making them if plotted immediately after returning to camp.

With such a skeleton of the main roads, showing all branches, the sketches could not go far wrong, and it was a simple matter in headquarters to transfer the sketch maps to the control sheet.

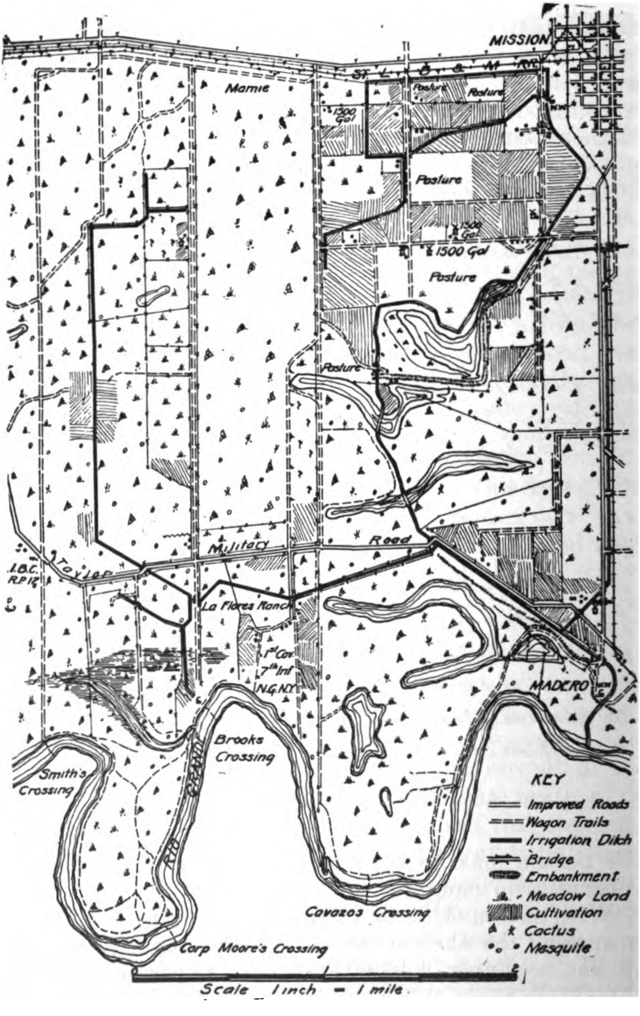


FIG. 107. SECTION OF MEXICAN BORDER MAPPED BY 22ND N. Y. ENGINEERS

The individual sketchers went out alone, and as many as sixteen were used at one time. They worked regardless of hours, catching rides on supply wagons or trucks when their work lay at a distance from the camp (often fifteen to twenty miles), and putting up at the nearest outpost or infantry camp when overtaken by darkness.

For the work near the river, a man was sent to each outpost, where he was attached for rations and made his home for a week or more, until his sector was completed.

Towards the close of the work, the automobile traverse being completed, sketchers were given control sheets covering three or four square miles, to be filled in. With this method, a daily rate of progress of two square miles per man was not unusual.

The total field work, covering about 200 square miles, was completed in less than one month's working time, and in much more detail (on account of the scale, $3'' = 1$ mi.), than the military map (scale: $\frac{1}{2}'' = 1$ mi.). The country was so flat that contouring by reconnaissance methods was impracticable, therefore no relief was shown. Drainage was largely by a chain of swamps and shallow lakes, into which surface water drained, to be evaporated or to find its way slowly to the river.

Fig. 107 shows a section of the map as made in this manner. The original scale of 3 inches to the mile was reduced to 1 inch to the mile in this reproduction.

Mapping by Range Finder. Machine gun companies and troops are now equipped with a self-contained range finder, consisting of a tube about 3 feet long and 4 inches in diameter, mounted at its center upon a light tripod. In one side, near the ends, are two windows, containing prisms.

These refract the fields of view to the center, where they are seen superimposed through an eye-piece in the center of one side, opposite the objective windows. An adjusting roller controls the angle of the end

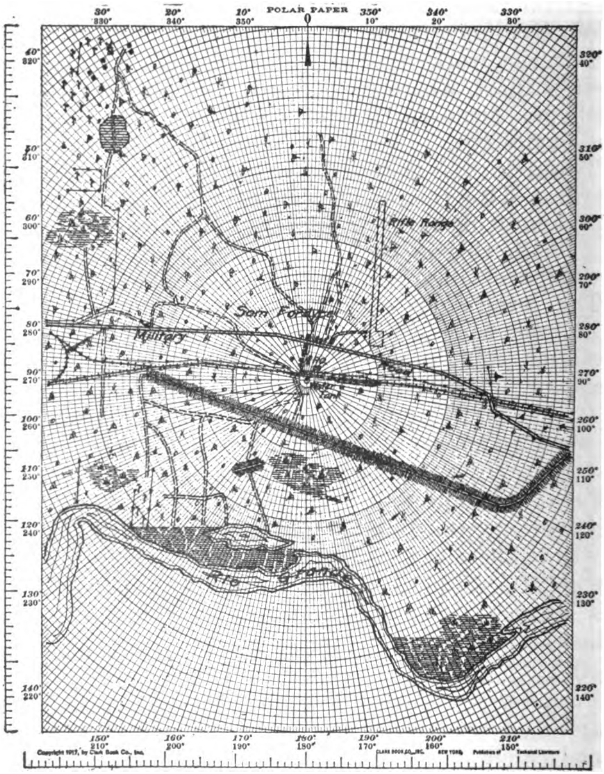
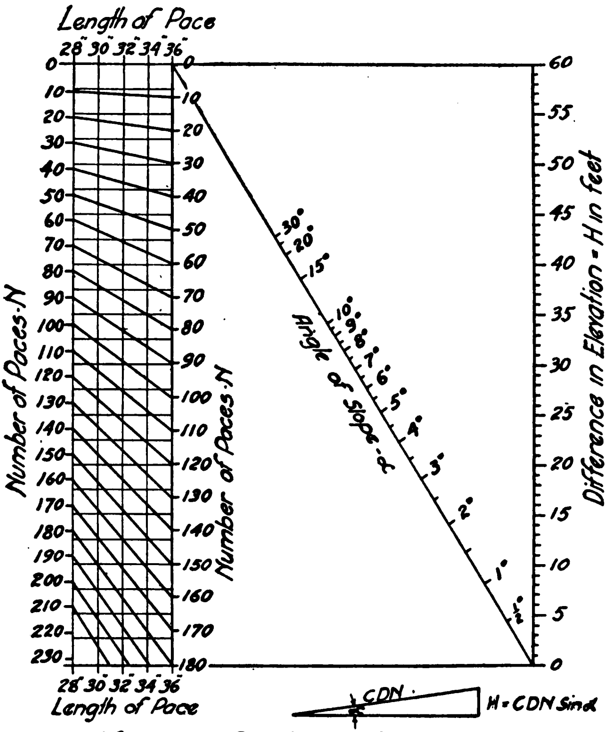


FIG. 108. TOPOGRAPHY BY SELF-CONTAINED RANGE-FINDER

RECONNAISSANCE DIAGRAM



H = difference in Elevation in feet
D = normal length of pace in feet
N = number of paces
C = coefficient (assuming D decreases 1½% per degree of slope)
α = angle of slope in degrees

For any pace length, find the intersection of the length of pace with the number of paces; project this point horizontally to 36" axis. Then a straight line between this new point & angle of slope, gives the corresponding difference of elevation on H-axis

N.B.P.

FIG. 109. SLOPE REDUCTION DIAGRAM

prisms, and consequently the position of the images in front of the eye-piece. A sliding scale is actuated by the same roller. When the two images, one from each end prism, appear in conjunction, the range may be read upon the scale. An accuracy of 0.5% may be attained with this three-foot base up to 1500 yards or more.

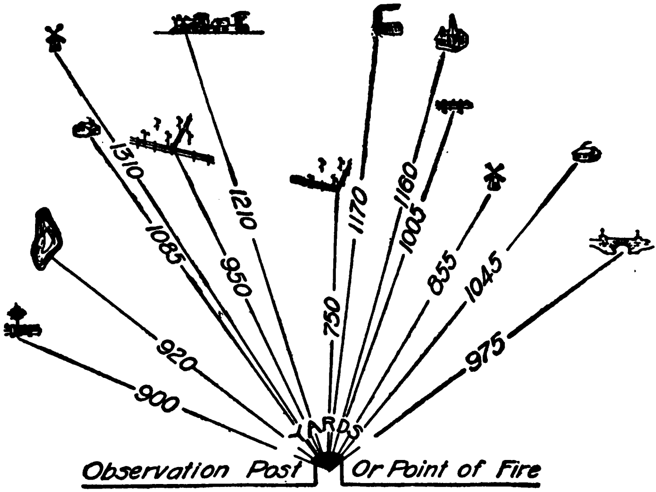


FIG. 110. RANGE CARD

The use of this instrument for topographical work was first suggested to the writer by an infantry officer of the regular service. Upon investigating, it was found to be feasible for very rapid work in a level country. The observer takes his post upon a building or other elevated point, reads distances by the range finder and directions by a prismatic compass. It is simply the stadia method without the rod-

man. The use of polar co-ordinate paper, as shown in Fig. 108, is a great aid to rapid plotting.

Contouring is impracticable by this method, but a rough sort of trigonometric leveling might be done by the clinometer for comparative elevations of nearby points.

Fig. 109 shows a diagram for computing elevations from slopes, devised by Master Engineer N. D. Richardson, 1st Battalion, 22nd N. Y. Engineers. Although designed primarily for use in conjunction with pacing, it may be employed for known distances, using 36-inch paces as yards. Such a diagram might be pasted upon the back of a sketching board and used in place of a scale of map distances (see Chapter XIII, p. 185).

A useful application of the range-finder method is in the making of a *range card* (Fig. 110). These cards are drawn up for the foreground of a defensive position and one is placed in each fire bay of the trenches.

Roads.

Most military roads, especially those built for military purposes, are dirt roads. Their greatest enemy is mud, for which the remedy is drainage. In a flat country, however, there is usually lacking a place to which the water may be drained.

In southern Texas the soil has no cohesion when dry and no bottom when wet. The roads were made by the simple process of driving across country, so that the scant vegetation was soon worn off, then the soil pulverized and blew away, and the road was below the grade of the surrounding country. During the rainy season they were never dry and large mudholes, a hundred yards or more long and the full width of the road, almost stopped motor trans-

portation. These mudholes would dry into a hard crust on top, presenting apparently a solid surface, but which would break under the load of a truck and let it down to the hubs in the liquid mud underneath.

The Engineers were called upon to repair some particularly bad mudholes, and found the job almost hopeless. The road was below the general surface, and could not be raised without an amount of fill beyond the capacity of the men or tools. No timber was to be had for corduroying, and there was not a stone in the country for metalling. No more substantial soil could be obtained for filling, and although deep ditches would have drained the road, they would have filled in the next rain and the water would have again covered the road.

Apparently the only course of action was to fill the mudholes with dry earth from the sides. This was done, and after completing about a twenty-foot section a motor truck came along, broke through the fresh earth and was hopelessly mired in the mud underneath. The fresh earth had not absorbed any of the water and the mud was as soft as ever under the fill.

The correct method of dealing with the mud-holes was therefore learned by bitter experience. *All* the mud had to be taken out and dumped at the roadside. Then the hole was filled with dry earth, directing the traffic so as to compact the fill as much as possible. The road was then crowned to insure the water's standing upon the *sides* of the road after a rain instead of in the center.

A number of bad mudholes were repaired by this method, and in some cases a plow or a road scoop could be obtained from neighboring farms, which greatly expedited the work, as the only engineer tools available were entrenching shovels and picks.

After the rainy season had passed, however, this filled-in earth pulverized into fine dust, much of which blew away, and some remained to become mud with the next rain. Almost continual work by a larger force than the Engineers could muster would have been necessary to maintain the roads within the maneuver area of the N. Y. Division.

The Engineers of the punitive expedition into Mexico had much the same experience with this soil. They tried various expedients, and finally, by the aid of road building machinery, built and maintained two roads for wet and dry weather, respectively. The wet weather road was graded to a higher level than the surrounding country and was therefore well drained. It became wet, but not deep in mud, as water could not stand upon it.

In dry weather, however, the surface of this road became pulverized and deep in dust, forming almost as much of an impediment to traffic as the mud.

It was found, however, that in dry weather the trucks could run across trackless country, which, as undisturbed soil, would stand considerable traffic before becoming dusty. A road was therefore laid out paralleling the graded road, and when the dust became too deep, it was removed by the roadscraper, leaving a wearing surface of the natural earth. Although water stood in this road in rainy weather it did not deteriorate, as there was no traffic to cut it up, and, similarly, the graded road did not pulverize in dry weather, as the traffic was shifted to the other road when it became dry.

Bridges.

Much of the work of the Engineers will consist of the reconstruction, repair or strengthening of bridges. If operating in a developed country original construc-

tion will be rare, as most of the roads will be well supplied with bridges.

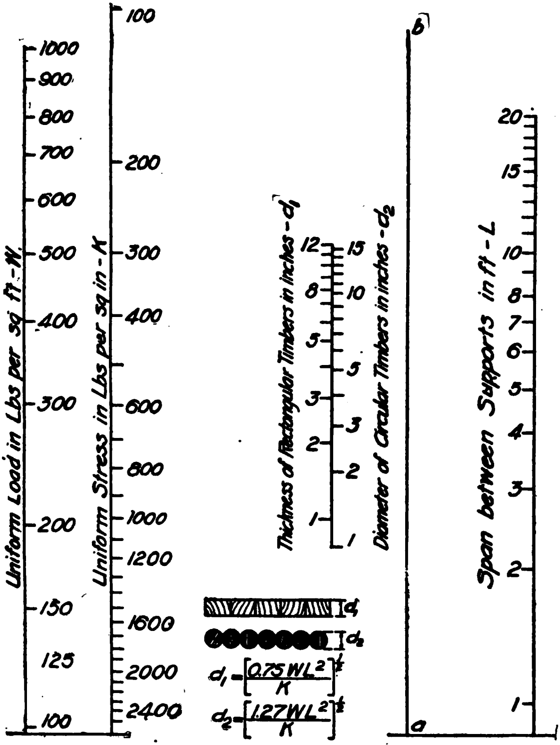
The simple pile bridge will be almost universally employed for replacements, even up to a considerable length, while there will be numerous beam bridges of probably only one or two spans which may delay a wagon train indefinitely if not in repair or for lack of proper strengthening.

The repair or strengthening of a large truss bridge is a job for the bridge carpenters and erectors with the line of communication troops, and not for the pioneers at the front, but ordinarily such bridges, if not damaged, will be strong enough to bear the army loads one at a time, or if destroyed recourse may be had to the ponton train or a pile bridge.

Bridge Reconnaissance. The maneuver territory of the New York Division in Texas was cut up by an intricate network of irrigation canals and ditches, with numerous bridges of the beam or pile type. These were not built for the heavy army trucks, and needed many repairs. The maintenance of these bridges fell to the Engineers, and in order to keep the records straight and simplify the organization of the work, a reconnaissance of all the bridges in the district was undertaken.

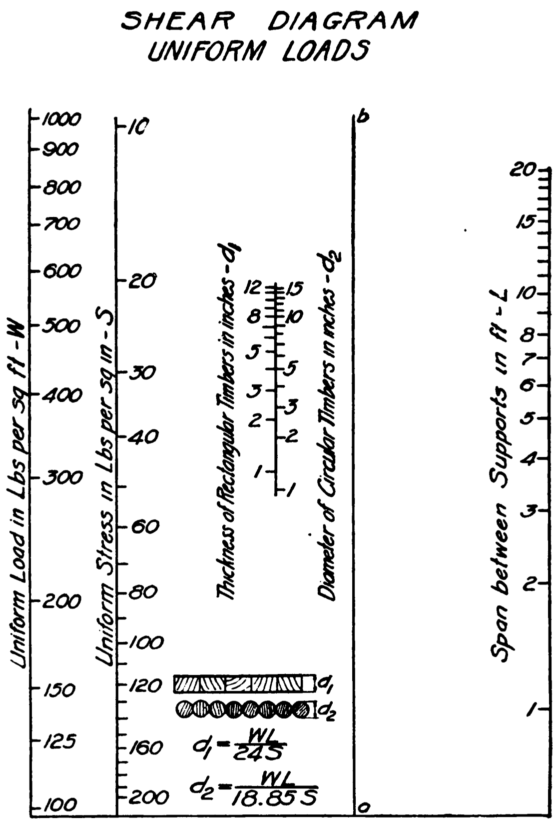
A system of identification was adopted, the bridge being known by a number and by the name of the road upon which located. A non-commissioned officer and one man set out mounted to measure the bridges and to obtain the required data about each, from which the office force could prepare the inspection reports. These men could measure only about ten or twelve bridges a day in this manner, however, and in addition they had trouble in fixing the distance between bridges by timing the horses. They were therefore sent out in an automobile and succeeded in covering over fifty bridges in a day, taking distances from

MOMENT DIAGRAM
UNIFORM LOADS



Find intersection of a line between values on the W & L axes with line a-b. A line from this point thru any point on the K axis, gives corresponding values on d_1 & d_2 axes.

FIG. 111. MOMENT DIAGRAM, BRIDGE DECKING



Find intersection of a line between values on the W & L axes with line a-b. A line from this point thru any point on the S axis gives corresponding values on d_1 & d_2 axes.

FIG. 112. SHEAR DIAGRAM, BRIDGE DECKING

the speedometer and obtaining full data regarding each bridge. This reconnaissance and the topographical work described earlier in this chapter emphasize the utility of one or more motor cars in an engineer organization. Both pieces of work would have been greatly delayed and perhaps never satisfactorily completed were it not for this one private motor car at regimental headquarters.

The labor of computing the safe loads upon these bridges was enormous, and was proceeding at a very slow rate, when the following set of diagrams were devised and constructed by Master Engineer Richardson, 1st Battalion.

The first, Fig. 111, can be used either for designing or for investigating the strength of bridge decking. It is applicable to rectangular or round timbers, and will give the unit stresses for any uniform load. Its use is explained by the note under the diagram.

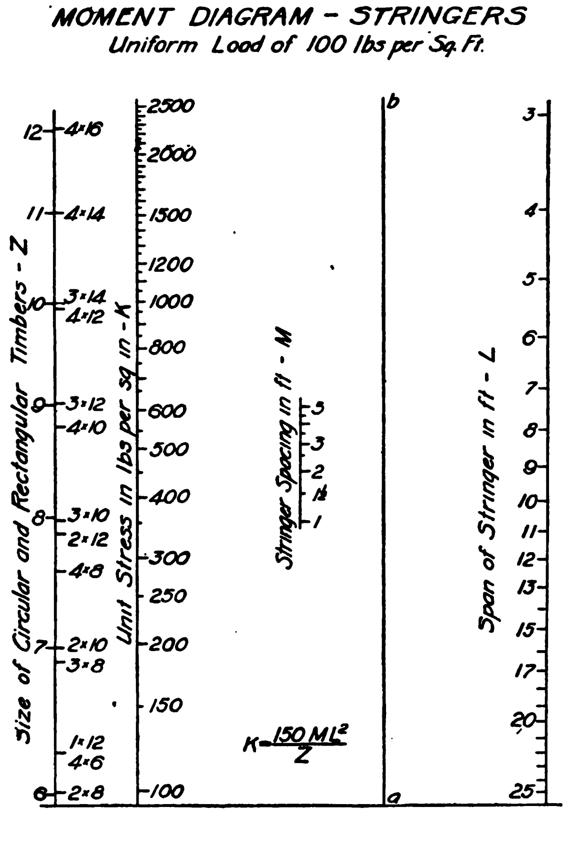
The second, Fig. 112, is similar to the first, but is designed for investigating the strength of the decking in shear.

Fig. 113 is similar to Fig. 111, but applies to stringers. Owing to the greater number of factors entering into its composition, it could not be made applicable to all loads, so 100 pounds per square foot was adopted as a figure not usually exceeded, and the diagram was worked out for this value. As in Fig. 111, it may be used for either round or rectangular timbers.

Fig. 114 is for investigating shear in stringers.

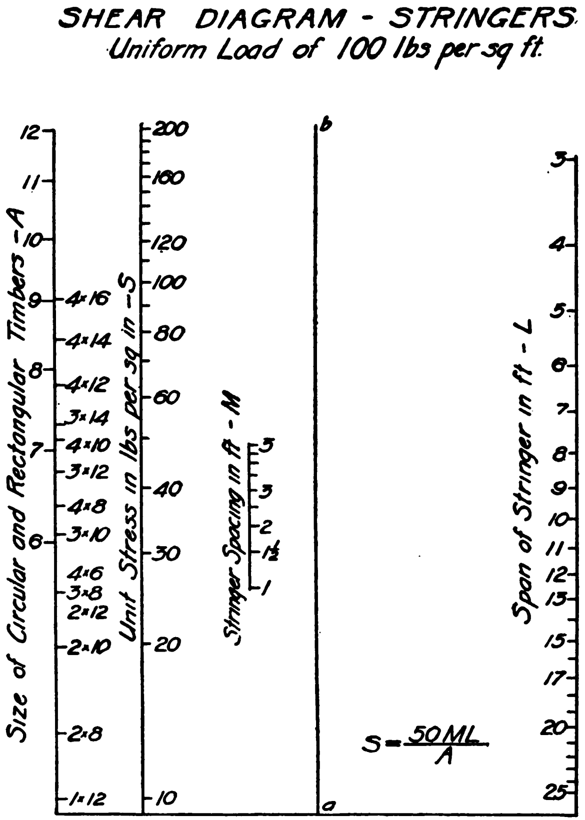
For the concentrated loads that travel with an army, the tables in Figs. 115 and 116 were designed.

The use of these tables is self-explanatory. They read unit stresses and shears direct. A five-ton motor truck has been taken as the standard, but as unit stress and shear are both direct functions of the load, they may be made applicable to any load, proportion-



Find intersection of a line between values on the Z & L axes with line a-b. A line from this point thru a point on the M axis will intersect the K axis at the corresponding unit stress.

FIG. 113. MOMENT DIAGRAM, BRIDGE STRINGERS



Find intersection of a line between values on the A & L axes with line a-b. A line from this point thru a point on the M axis will intersect the S axis at the corresponding unit Stress.

FIG. 114. SHEAR DIAGRAM, BRIDGE STRINGERS

ing the conversion factor to the *load upon each wheel.* For instance, a two-wheeled gun carriage of

FLOORING STRESSES - CONCENTRATED LOADS

Assume Load of 5 Tons on two - 5 ft axles - 8 ft apart

MOMENT STRESSES

$K = \frac{3Pm}{Z}$

m not > 5'.0" or two wheels may affect span

K = moment stress in #/sq in
P = wheel load in lbs.
m = stringer spacing - in ft.
Z = section modulus of floor plank = $bd^2/6$ (Rect)
= $0.098D^3$ (Cir.)

SIZE OF FLOOR PLANKS

m Span	2"x6"	2"x8"	2"x10" (4" Dia. ϕ)	2"x12"	3"x6"	3"x8" (5" Dia. ϕ)	3"x10"	3"x12"	4"x4"	4"x6"	4"x8" (6" Dia. ϕ)	4"x10"	4"x12" (7" Dia. ϕ)
1.0	1870	1405	1125	937	833	625	500	417	700	468	351	281	234
1.5		2110	1690	1405	1250	940	750	625	1050	703	527	422	352
2.0			2250	1875	1665	1250	1000	833	1410	938	703	562	468
2.5				2340	2080	1565	1250	1040	1765	1172	878	703	586
3.0					2500	1875	1500	1250	2110	1410	1055	843	703
3.5						2090	1750	1460	2460	1645	1230	983	820
4.0						2500	2000	1670		1880	1405	1125	938
4.5							2250	1875		2110	1580	1265	1055
5.0							2500	2080		2350	1755	1405	1172
m													

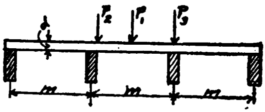
SHEARING STRESSES.

$S = \frac{P}{A}$

S = shearing stress in #/sq.in
P = wheel load in lbs.
A = area of stringer = bd ϕ
= $\frac{\pi D^2}{4}$ ϕ

SIZE OF FLOOR PLANKS

SIZE	2"x6" (4" Dia. ϕ)	2"x8"	2"x10" (5" Dia. ϕ)	2"x12"	3"x6"	3"x8"	3"x10" (6" Dia. ϕ)	3"x12"	4"x4"	4"x6"	4"x8"	4"x10" (7" Dia. ϕ)	4"x12"
Stress	208	156	125	104	139	104	84	70	156	104	78	63	52



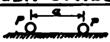
For moment on flooring place wheel halfway between stringers (P_1)
" shear " " " " at side of stringer. (P_2)
" moment or shear on stringer - place wheel directly over stringer. (P_3)

FIG. 115. STRESSES IN DECKING, CONCENTRATED LOADS

the same total weight as the motor truck would cause *twice* the unit stresses and shears due to the

motor truck wheel. Of course, if the two axles of the truck were in the same span, this ratio would not hold for the bending stress in the stringer. The ratio based upon relative wheel loads holds good up

STRINGER STRESSES UNDER CONCENTRATED LOADS.



Assume load of 5 tons on 2-5 Axles 8 feet apart
Max spacing of stringers = 5'0" c/c

P = wheel load in lbs.
l = span of stringer in feet
a = space bet. axles in feet
b = breadth of stringer in in
d = depth
Z = section modulus = $\frac{bd^2}{6}$
K = moment stress in lbs/sq in

Spans $< \frac{a}{.586}$, $K = \frac{3Pl}{Z}$

Spans $> \frac{a}{.586}$, $K = \frac{6P(l-\frac{a}{2})^2}{Zl}$

MOMENT STRESSES.

SIZE OF STRINGERS.

SPAN FT.	1"x12"	2"x8" 6" Dia.	2"x10" 7" Dia.	2"x12"	3"x8"	3"x10" 8" Dia.	3"x12" 9" Dia.	3"x14" 10" Dia.	4"x6"	4"x8"	4"x10"	4"x12"	4"x14" 11" Dia.	4"x16" 12" Dia.
3	937	1055	677	468	703	450	312	229	937	527	338	234	172	132
4	1250	1410	902	625	938	600	417	306	1250	702	451	313	229	176
5	1564	1760	1125	782	1170	750	522	373	1560	877	563	391	286	220
6	1875	2110	1350	938	1405	900	624	458	1875	1052	675	469	344	263
7	2186	2460	1580	1093	1640	1050	728	536	2190	1226	790	547	402	307
8	2500		1800	1250	1875	1200	833	613	2500	1400	900	625	458	351
9			2030	1405	2110	1350	937	688		1580	1015	703	516	395
10			2250	1562	2350	1500	1040	765		1752	1125	781	573	438
11			2480	1721	2580	1650	1144	842		1930	1240	860	630	483
12				1875		1800	1250	918		2110	1352	938	687	528
13				2030		1950	1352	995		2280	1462	1015	745	571
14				2230		2140	1488	1092		2510	1610	1115	818	627
15				2520		2420	1680	1250			1820	1260	924	708
16							1875	1375			2030	1405	1030	790
17							2070	1525			2240	1552	1138	873
18							2270	1666			2450	1700	1246	955
19							2470	1812				1850	1355	1040
20								1960				2000	1465	1122
21								2110				2150	1580	1210
22								2270				2310	1700	1300
23								2400				2450	1800	1375
24													1910	1461
25													2020	1545

Spans $< a$, $S = \frac{P}{A}$

Spans $> a$, $S = \frac{2P(l-\frac{a}{2})}{Al}$

P = wheel load in lbs
l = span in feet
$A = bd$ = area of stringer in sq. in
S = shearing stress in lbs/sq. in

SHEARING STRESSES.

SIZE OF STRINGERS

SPAN FT.	1"x12"	2"x8"	2"x10"	2"x12"	3"x8"	3"x10" 6" Dia.	3"x12"	3"x14"	4"x6"	4"x8"	4"x10" 7" Dia.	4"x12" 8" Dia.	4"x14"	4"x16" 9" Dia.
1 to 8	208	156	125	104	104	84	70	60	104	78	63	52	45	39
9		173	139	115	115	94	78	67	115	87	70	58	50	43
10		187	150	125	125	101	84	72	125	94	76	62	54	47
11		199	159	133	133	107	89	77	133	99	80	66	57	50
12			167	139	139	112	93	80	139	104	84	69	60	52
13			173	144	144	116	97	83	144	108	87	72	62	54
14			179	149	149	120	100	86	149	111	90	74	64	56
15			183	153	153	123	103	88	153	114	92	76	66	57
16			188	156	156	126	105	90	156	117	94	78	68	59
17			191	159	159	129	107	92	159	119	96	80	69	60
18			194	162	162	131	109	94	162	121	98	81	70	61
19			197	165	165	133	111	95	165	123	100	82	71	62
20			200	167	167	134	112	96	167	125	101	83	72	62
21				168	168	136	113	97	168	126	102	84	73	63
22				170	170	137	115	98	170	128	103	85	74	64
23				172	172	139	116	99	172	129	104	86	75	65
24				174	174	140	117	100	174	130	105	87	76	65
25				175	175	141	118	101	175	131	106	87	76	65

N.D.R.

FIG. 116. STRESSES IN STRINGERS, CONCENTRATED LOADS

to a stringer span of $\frac{1}{0.586}$ × the distance between the truck axles, $= 1.71 \times 8 = 13.68$ feet.

Compared with the usual long formulas and rules of thumb given in text books for determining the bearing power of bridges, these diagrams are a great improvement. Their accuracy is equal to that of the formulas and greater than that of the empirical rules proposed. Furthermore, the saving in time is a great factor, not only in the actual computation, but in the searching of text-books for the proper rules and formulas.

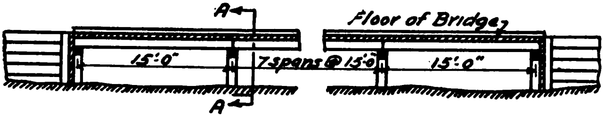
In applying these diagrams the condition of the timber is allowed for by choosing the working stresses. Moreover, there is an additional factor of safety in the continuity of the decking, causing action as a continuous beam and consequently lower stresses. Also, this continuity operates to reduce the load upon the stringer. As the stringer under the wheel deflects, the stiffness of the decking transmits a portion of the load, sometimes as much as 40%, to adjacent stringers. This cannot be allowed for in the diagrams, owing to the probability of joints in the decking, and so may be considered only as additional strength.

The diagrams may be used to investigate the wood floor system of a highway bridge of several panels.

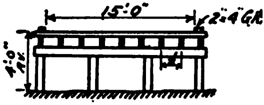
The bridge inspection reports were made up as shown in Figs. 117 and 118, each with a cross-section and profile of the bridge, its dimensions, location, condition, and safe load as computed by the diagram. These reports were prepared in strips, one strip to a road, so that a bridge report could be sent out complete with each map of a proposed line of march.

The engineer officers, in their maneuver marches and road repairing expeditions, would list all bridges needing repairs and send these reports, with an esti-

MC ALLEN-HIDALGO ROAD
NO 1 BRIDGE AT END OF LAKE



Side Elevation



Section A-A

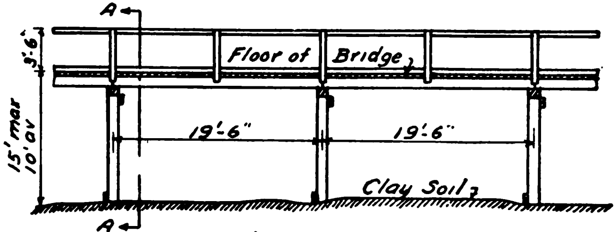
Total Length = 135 ft
9 spans - 15'-0" long
Flooring - 3"×12"×16'-0"
Stringers - 3"×12"×16'-0"
Floor beams - 8"×8"×16'-0"
Piles - 8"×8" ф
Material - cedar.
Condition - Good throughout
Bridge spans marsh at end of lake

Strength of Bridge
Assuming 800# per sq. in. for moment and 100# per sq. in. for shear, the allowable uniform load on bridge = 85# per sq. ft. (governed by moment stress in stringers)
A 5-ton motor truck with axles spaced 8 ft cts. gives the following stresses, showing need of reinforcement

Members	Moment	Shear
Flooring	833 lbs/sq.in	70 lbs/sq.in
Stringers	1,680 "	103 "
Floorbeams	330 "	59 "

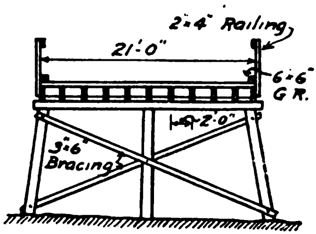
FIG. 117. BRIDGE INSPECTION REPORT

Sharyland - Granjeno Road
No. 4 Bridge at Rifle Range



Side Elevation

Total length = 856'
44 spans - 19'-6" long
Flooring - 3"x8"x21'-0"
Stringers - 3"x14"x20' 6"
Floor Beams - 12"x12"x22'-0"
Piles - 10" av diameter
Material yellow pine
Condition - good



Section A-A

Bridge spans dry valley
with 20 ft irrigation ditch
near south end

Assuming 1000#/sq.in for moment & 100#/sq in for shear.
Allowable uniform load = 87#/sq ft. (governed by
moment stress in stringers)
A 5-ton motor truck with axles spaced 8-ft apart gives
the following stresses, showing need of reinforcement

Members	Moment	Shear
Flooring	1250#/sq.in	104#/sq.in
Stringers	1886 "	95 "
Floor Beams	390 "	26 "

FIG. 118. BRIDGE INSPECTION REPORT

mate of the men and materials needed, to regimental headquarters. If the camp quartermaster could be induced to supply a truck and some lumber, it usually

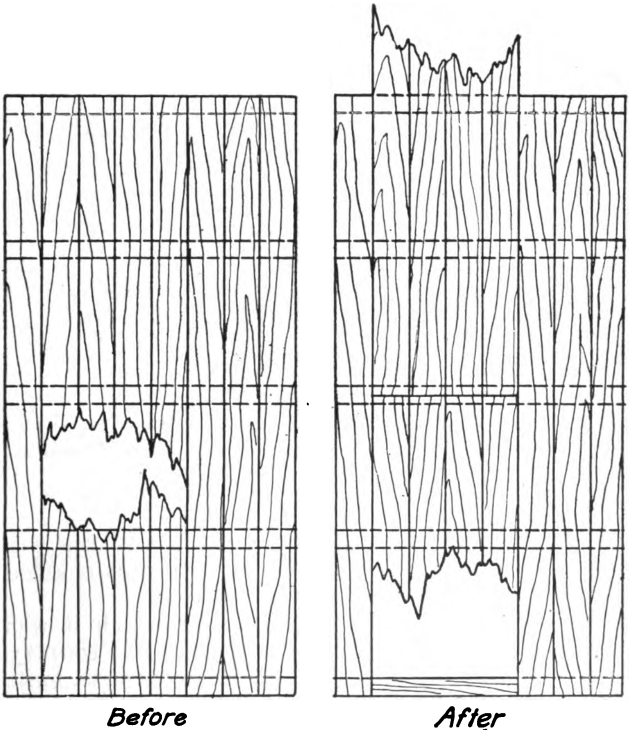


FIG. 119. REPAIRING BRIDGE DECKING WITHOUT NEW LUMBER

was not long before a working party was on its way to the scene. The Engineers were considerably handicapped by lack of motor transportation of their own.

When other troops reported a broken bridge, an officer was sent out in a motor-cycle side-car, of which one, privately owned, was available. He would be back in a couple of hours with full information as to the required repairs and an exact location of the bridge by the motor-cycle speedometer.

Bridge Repairs. The repair of a wooden bridge deck is a simple matter for any man who can wield a saw and hammer. Fig. 119 shows how this was accomplished in several cases without new material, by taking up the broken planks and reversing them

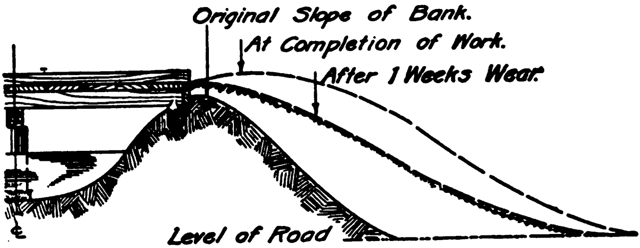


FIG. 120. REPAIRING BRIDGE APPROACHES

with a butt joint over one stringer. Marching columns with wheeled transportation were thus enabled to proceed with little delay.

Fig. 120 shows a common condition which it was frequently required to correct. In the flat country of southern Texas, the irrigation canals were all built above the ground level. This necessitated steep approaches by ramps, which were often found as shown, necessitating considerable filling before they became practicable for army trucks.

Strengthening Bridges. The strengthing of bridges in the field is usually limited to the simple beam or pile types, or to the floor systems of truss bridges.

If the decking is weak, it may be saved by running

the wheels over or as near the stringers as possible, as in Fig. 121(a). This method was used a number of times with a particularly heavy load, a water tank mounted upon a truck, and prevented broken floors in each case.

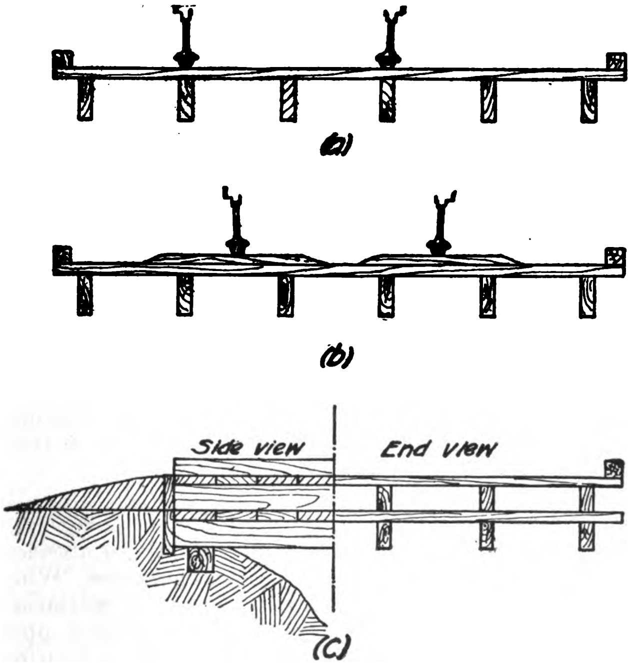


FIG. 121. STRENGTHENING DECK OF BRIDGE

The method shown in Fig. 121(b), by laying extra tracks under the wheels, will not only increase the strength of the decking, but of the whole floor system, by better distribution of the load to the stringers. That in Fig. 121 (c), of laying an entire new

floor system, stringers and decking, upon the old floor, will add greatly to the strength. Care must be taken that the new stringers overlap the abutments. All these methods may be applied not only to beam bridges as shown, but to the floor systems of truss or pile bridges as well.

Fig. 122(a) shows a method of strengthening the stringers of a bridge by shortening the span, as the unit stresses vary with the square of the span. The struts may be placed under each stringer or under those which carry the wheels.

Fig. 122(b) shows how this may be applied to a pile bridge. At the left the braces support transverse floor beams, and at the right braces must be applied to each stringer, or to those under the wheel tracks, as in (a).

Fig. 122 (c) shows an inverted king-post, formed of a strut and wire ties, which are tightened by twisting. If the floor beam at the top of the strut is omitted, only the stringers actually trussed in this manner will be strengthened. This method may be made applicable to the floor system of a truss bridge.

STAFF OFFICERS OF ENGINEERS.

Ordinarily there are no engineer officers attached to the staffs of the various unit commanders. When engineer troops are serving with an organization, their commander becomes the engineer officer upon the staff of the commanding officer of the division, brigade or regiment to which attached. He remains a line officer, while performing staff duty.

The functions of the Engineer staff officer are advisory in character. He recommends the undertaking of various engineering works as their need becomes apparent to him. He uses his engineer personnel to prepare plans for executing the work,

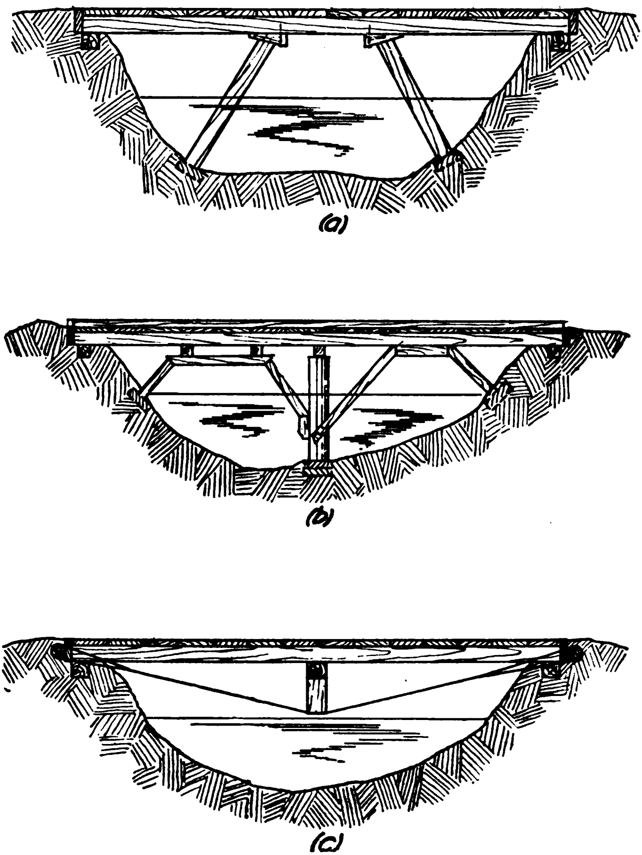


FIG. 122. STRENGTHENING STRINGERS OF BRIDGE

and when the plans are approved, for carrying them into effect, calling upon the infantry for such working parties as are required.

An engineer regiment is frequently split up and the sub-divisions assigned to different brigades or even regiments. Their general function is to assist the infantry in the work at hand.

Entrenching. When the division or brigade is assigned to a sector for defense, the commanding officer and the engineer study the situation from maps and, if possible, by personal observation of the site, determine the location and character of the defensive works.

The engineer then assigns to each particular work an officer and a number of men to supervise and assist in its construction. He determines the size of details required from the infantry and makes requisition to the chief of staff for the necessary working parties. He also orders tools and materials sent up from the Engineer Train.

The officer assigned to a section of the entrenchments collects his detail of engineer non-commissioned officers and men and proceeds to the site with stakes, tracing tape and tools. If possible, all the preliminary work is done before the arrival of the working parties, so that they may be placed on the line immediately upon reaching the site.

1st. The work is traced out with tape in accordance with the location and type decided upon by the chief engineer and probably marked as to general line by a few tall stakes.

2nd. The tools are piled ready for distribution. Sometimes these are laid out along the line, marking out the task of each man.

3rd. Details of engineer troops are told off for the more difficult construction, as framing for bombproofs, etc.

4th. Various engineer non-commissioned officers and privates are detailed along the line to supervise the work of the infantry.

When the working parties arrive, they are placed upon the line by the engineer officer in charge.

Picks and shovels are placed in two piles, each in charge of an engineer soldier. The infantry pass between these piles, and each man is handed both a pick and a shovel. They march in single file along the traced line of entrenchments, are halted and faced to the front. Shovels are laid down and intervals taken by each man grasping the wrist of the man on his left. Each man then drives his pick into the ground on the line, opposite his right foot. The interval between his pick and that upon his left (about five feet) is his task.

Reliefs are drawn up in rear of the line at a preliminary signal and at the signal for changing, the first relief lay their tools upon the edge of the trench and step out, the second relief taking their places.

Another method of placing men upon the line is practiced in the British service. Tools are laid out along the line, which may or may not be traced out. The officer paces off the line, posting a man at each two paces. The men then count off by six or eight, depending upon the proposed distance between traverses. Numbers one and eight step two paces to the rear and dig around the traverses. This method is said to be particularly satisfactory for night work.

While the trenches are under construction, a party under the supervision of engineer soldiers proceeds to clear the foreground.

Selection of Camp Sites. When organizations are to go into camp, usually in brigade units, the division engineer, from the map, selects a camp site and an alternate site. The engineer officer with the brigade examines the location, and consults with the medical officer as to the quality of water. If not satisfac-

tory, he will make an examination of the alternate site.

The division engineer and the surgeon inspect the site finally selected, and may condemn it if unsatisfactory. When finally approved the camp is staked out as described in Chapter XVIII. (See Fig. 123). A sketch should be prepared for each arriving organization showing the layout, together with its position among other units.

The engineer officer then causes to be marked with sign boards the places for obtaining water for drinking and cooking, watering animals, bathing and washing clothes.

Communications. The brigade engineer ascertains where new roads or bridges, or repairs to existing ones, are required to facilitate communications, and reports the same to the division engineer. Upon receiving authority to proceed with the work he organizes his forces and requests the necessary details from the infantry.

The engineer officer details officers and men to improve roads, bridges and water supply, assisted by working parties from the infantry.

If a camp is intended for long occupation, the engineer officer will design shelters for the men, taking into account the material available. The Engineers collect what can be found, and requisition is made upon the quartermaster for the remainder. The Engineers instruct the other troops in the construction of these shelters.

CHAPTER XVIII.

SANITATION.

Camp sanitation is largely a matter of engineering, coupled with discipline. The health of a command is preserved, and its fighting strength maintained, by:

First, excluding from the service the physically unfit and those predisposed to disease.

Second, by the exercise of surgical and medical skill in promptly restoring to duty the wounded and sick.

Third, and by far the most important, preventive measures, consisting of:

(a) The various vaccinations, innoculations and prophylactic treatments tending to increase individual powers of resistance to disease or to prevent the development of disease after infection.

(b) Camp sanitation, or measures taken to secure healthy living conditions in camp.

Of these, all are the special province of the Medical Corps, except (b) under the third heading, which is sanitary engineering applied to camp conditions, under the supervision of and subject to inspection by officers of the Medical Corps.

The engineering problems connected with camp sanitation comprise:

1. The selection and laying out of camp sites, or *castramentation.*
2. Water supply.
3. Drainage.
4. Disposal of refuse.
   (a) Animal wastes.
   (b) Garbage.
   (c) Rubbish.

THE SELECTION AND LAYING OUT OF THE CAMP SITE.

The considerations for a good camp site are many and are seldom obtainable in any one location. According to the Field Service Regulations, U. S. Army, they are as follows:

First, good drainage.

Second, sufficient space to accommodate the troops without crowding.

Third, an abundant supply of good water.

Fourth, good communications to and through the camp.

These considerations usually require a slightly sloping plain with sandy or gravelly subsoil, covered by closely cropped turf. In hot weather shade is desirable, and in winter a southern slope, with woods to break the north winds. The high bank of a river, if not in the vicinity of marshes, is a favorable location.

Old camp grounds, the vicinity of cemeteries, dense forests and undergrowth, made ground, depressions, ravines, etc., are to be avoided. Ground at the foot of a slope is usually damp and therefore unfavorable, and swamps or stagnant water in the neighborhood will breed mosquitoes.

In laying out the camp it is desirable to arrange the communications so that troops will not have to pass though the camp grounds of another organization to reach their own.

In the presence of the enemy, tactical considerations often govern, and troops may be forced to camp in unsuitable locations. In such cases the best should be made of unfavorable conditions, and everything possible done to offset them.

When a camp is designed for continuous occupancy, however, the preparation of the site becomes a problem in municipal and sanitary engineering.

Fig. 123 shows the typical layout for the camp of a regiment of infantry. Those for other troops are similar, except that space for picket lines, gun parks,

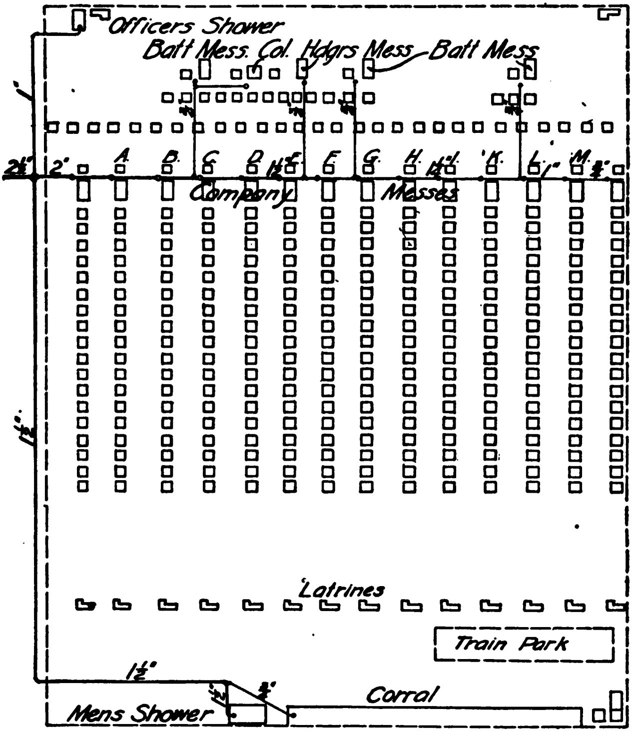


FIG. 123. CAMP OF A REGIMENT OF INFANTRY.

etc., are provided at the lower ends of the company streets, in prolongation of the lines of tents, for mounted troops, artillery, etc. In laying out such

a camp, it is usually sufficient to mark by a stake the head of each company street, headquarters, officers' messes, company officers' line, field officers' line, and the lines of latrines, leaving to the organizations pitching camp the spacing of their tents in parallel rows. In an emergency, and for temporary occupation, the camp of a regiment of infantry may be contracted to a space 160 yards by 180 yards, covering 6.2 acres.

A large camp is a collection of regimental camps, with the auxiliary troops fitted in wherever they may find space. A good arrangement is side by side, the officers' street continuous through the several organizations, with roads separating the regimental units. Where more than one row is required, the camps should be placed back to back, i.e., stables and train parks of one row adjoining those of another, or the officers' rows adjoining. The foot of one regimental camp should not be placed adjacent to the officers' quarters of another. Such an arrangement would bring the stables, etc., of the one organization too near the kitchens of the other, besides the inconvenience to the officers concerned. The main highways of the camp are ordinarily located between the rows of regimental camps.

It is seldom that a level area large enough to accommodate the camps of the various organizations in regular order is available, and the camp must be fitted to the ground, due attention being given to preserving the integrity of brigades, etc.

Once occupied, a camp is continually being improved by the troops; officers' and company streets are crowned, curbs and gutters formed, drainage provided, gutters bridged, streets oiled, etc.

WATER SUPPLY.

Sources.

City Water Supplies. The simplest solution of the water supply problem in a permanent camp is a connection with the mains of a neighboring city. For many reasons, however, large camps are not usually located in the immediate vicinity of large cities, and the water systems of the smaller towns are generally unequal to the increased drain upon their supply. In case such a plan can be carried out, care must be taken to connect with the main feed system of the town and not with small outlying branches, incapable of supplying the camp.

Streams and Lakes. The ideal source of this character is a mountain stream, whose water is cool and pure, and whose course includes a good site for a reservoir, located at a sufficient elevation to permit of gravity distribution. A lake forms a natural reservoir, whose storage capacity is usually above all possible demands of the camp.

A country whose topography favors the construction of reservoirs and gravity systems of supply, however, will seldom afford sufficient level ground upon which to locate a large encampment, except at the cost of a long supply line. The usual method of procedure, therefore, will be to pump the water required and to erect tanks upon the highest available ground, preferably in a central location, for gravity distribution.

Surface water is usually open to suspicion, unless the source be thoroughly inspected and no actual or potential source of pollution be found to exist. However, the methods of disinfection of water by chlorine and by the hypochlorites of calcium and sodium, in successful use for a number of years in civil practice, are now being adopted for military use, and almost

any water, unless actually containing raw sewage, may be made safe for drinking by the installation of a chlorination plant.

Wells. Drilled or driven wells, especially those of some depth, are the most satisfactory source of supply. The water is usually of better quality, is cooler, and is not so liable to accidental pollution as surface water. Where time permits the driving of wells and a sufficient supply may be obtained in this manner, the results will more than justify the additional expense and the increased amount of pumping.

Pumping.

The most satisfactory system is by gasoline engines, on account of their portability, availability of fuel, and ease of operation. The duty is not constant, as there is no use of water at night, and the draft is concentrated in well defined periods during the day. The preparation of each meal, watering of animals, morning washing, and bathing at the conclusion of afternoon drill cause the heaviest drafts. As the morning washing and watering of animals coincide with the preparations for breakfast, and afternoon bathing and watering with those for supper, it may be considered that the three mess periods constitute the times of greatest draft.

Practically all the water used, therefore, is between four A. M. and eight P. M. About 50% of this is concentrated between four P. M. and seven P. M., and 25% between five A. M. and seven A. M. The tanks, therefore, should be capable of storing an amount equal to 50% of the total daily supply, or 12-15 gallons per man and 6-8 gallons per animal. These tanks should be entirely full by four P. M. and again by four A. M. The pumping might well be limited to two periods, therefore: the early afternoon and the late evening.

The pumping plant should be in two or more units, in case one should break down. It is scarcely necessary to have a reserve pumping capacity, as a breakdown is not liable to prove of long duration, and the use of water is entirely under military control, insuring a supply for the most important uses, even if the total supply is somewhat restricted.

Distribution.

The camp should be laid out so as to facilitate as much as possible the distribution, by avoiding long lines between units. The piping system for a regiment of infantry, as shown in Fig. 123, is practically standard, and the arrangement of the main feeders for a regularly laid out camp does not present any difficulties. The usual error is to make them too small. Valves should be placed at the entrance to each camp and on all mains just beyond each regimental branch, so as to permit the supply of as many organizations as possible while a section of the main is undergoing repairs. A loop system is desirable if permitted by the ground plan of the camp, as then a break in the main will necessitate cutting off the water from only one or two camps.

For the camp of a regiment of infantry at war strength, about 20 taps are required, one for each mess, one for the corral, and one for the commanding officer. The main feed pipe should not be less than 2½ inches; reducing to 2 inches after the bath and corral lines have been taken off; to 1½ inches at the end of the first battalion, and to 1¼ inches at the end of the second. Lines supplying a single tap are ¾ inches. The officers' bath should be provided with about four shower heads and that of the men with about forty.

Few military organizations will be found which do not contain some men with a practical knowledge of

steam fitting or plumbing. Certainly no engineer troops will be without such men. These can instruct others detailed as helpers, and the whole command will soon be able to put in pipe at an almost unbelievable rate.

In June, 1915, at Fishkill Plains, N. Y., in preparation for a re-enforced brigade encampment, two officers of the 22nd N. Y. Engineers and fourteen men, in eleven days, laid two miles of pipe, varying in size from 4-inch to ¾-inch, erected two tanks of 15,000 gallons capacity each and one smaller, installed 105 hydrants, three pumps and engines, and twelve bath houses, totaling 108 shower heads.

On June 20, 1916, Camp Whitman, Greenhaven, N. Y., was occupied by the 22nd N. Y. Engineers, with instructions to construct a system of water supply so as to permit the mobilization of 20,000 troops at this point. In preparation for a summer encampment, a survey had been made and a tentative layout prepared for a distribution system, but the material was just commencing to arrive, and no work had been done. The two battalions were put at the work on June 21st, and a contractor began drilling the wells. On June 25th the 1st Battalion was taken off to prepare for immediate transfer to the Mexican Border. The 2nd Battalion continued alone, and by June 29th a 50,000-gallon tank had been erected upon concrete foundations, a pumping plant installed, and water supplied to ten camp sites, through a six-inch main loop and various branches. By that time every man in the organization could lay pipe.

Pipes for a camp should be covered, as they are then better protected from injury, and the water is kept cooler, which prevents much waste in running water from the taps to obtain a cool drink. It is usually not necessary to dig a trench, unless the camp is to be occupied in freezing weather. Ordi-

narily the pipes may be laid in a plowed furrow and the earth raked back upon them. For ease in assembling, the pipe may be laid flat upon the ground, and each organization required to cover its own pipes and the mains half way to the adjoining branches. Hydrants are usually provided with self-closing faucets, to prevent waste, but their utility is doubtful. There is no type yet invented that cannot be tied, wedged, or otherwise held open when the soldier so desires, and as the use of water is under full military control, cases of faucets left running are not frequent. In the showers, weights are tied upon the levers of self-closing cocks, bending them and eventually breaking them off and rendering the shower unserviceable. A plain stop cock with a lever handle is cheaper, more serviceable, and would result in little more waste of water. Bathing may be restricted to certain hours and a guard placed to see that the water is turned off after using, if it is thought that too much water is being used.

Valves should be covered by boxes with padlocked lids, to prevent malicious or mischievous interference. Sometimes the hand wheels are removed to accomplish this purpose, but they cannot be carried around as can a key, are never at hand when wanted, and a monkey-wrench is used on the stems, deforming them until the wheel cannot be used.

Water Supply in Campaign.

With troops upon the move, camp sites are selected in advance of their arrival, and such selection is influenced largely by the available water supply, as to both quality and quantity.

Surface water will nearly always supply such camps, except where good springs or wells are available. The first duty of an organization arriving in

camp is to post a guard over the water supply, to enforce its proper use. If a stream, places are designated and marked, reading downstream in the order named, for obtaining drinking and cooking water, watering animals, bathing, and washing clothes.

A spring may be enlarged by digging or by blasting, if in hard ground or rock, and protected from surface drainage by a curb of stones and clay.

Cooking water may be used directly from the stream if clean, as the heat will usually kill all pathogenic germs. Drinking water, however, should not be so used unless of known purity. Where its character is the least in doubt, it should be made safe by sterilization. The method formerly employed for accomplishing this was by boiling. This could not always be enforced, owing to the time and fuel required, the difficulty of cooling the water afterwards, and the flat, insipid taste of the boiled water.

The chlorination method of sterilization has been adopted in the Army, and simplifies the problem greatly. The liquid chlorine treatment, though probably the most efficient, is not adapted to military field use on account of the apparatus required. Of the hypochlorites, that of sodium, in liquid form, is more efficient for its bulk, but that of calcium (bleaching powder, is ordinarily the more readily obtainable. The latter, however, when loose or packed in cardboard, loses its strength very rapidly. It is best kept by making up and bottling a strong stock solution.

The strength used in sterilizing municipal supplies is 0.2 parts per million, that in the field about ten times as great, or 2.0 parts per million. In the former case fresh powder, from air-tight drums, is usually available, the mixing is more thorough, and the distribution more carefully regulated. Usually, also the water has been partially purified by sedimentation in a reservoir. In such cases, twenty min-

utes is supposed to render the water safe for drinking.

For field use, a level teaspoonful of calcium hypochlorite (chloride of lime) is dissolved in two quarts of water for a stock solution. One *teaspoonful* of this solution is added to a gallon of water, or ten *tablespoonfuls* to a barrel. The water is considered safe to use after standing for thirty minutes.

A sterilizing bag, of linen fabric, holding about forty gallons of water, is issued to troops in the field. As the chemical acts better in clear water, a filter cloth is provided to strain it in filling the bag. The sterilizing medium is calcium hypochlorite, sealed in glass tubes, which are marked with a file to facilitate breaking them without fragments. They each contain about 15 grains of the chemical, which gives a proportion of 2.0 parts per million, sufficient to destroy germ life in even highly infected, though not in sewage polluted, waters.

The bag is covered to keep out dust, and the water is cooled by the evaporation of the moisture which exudes through the fabric. Water is drawn off through small self-closing faucets set in a circle around the bag, slightly above the bottom.

DRAINAGE.

A camp site requiring extensive drainage operations to make it habitable should not be adopted, as even when drained it will remain damp for a long time. Occasionally, however, sites are found which are otherwise favorable, but upon which water may be inclined to stand after a heavy rain. A simple system of ditches, constructed by the troops themselves, will usually remedy this defect. The camp should never be sited upon the lowest ground in a neighborhood, even if perfectly dry, as drainage during and after rains will then be very difficult.

The interior drainage of the camp is taken care of by gutters along the company streets, and by crowning the latter to avoid puddles and mudholes. Ditches are dug around the tents, directly under the canvas walls, with the earth banked up *inside* the tent. These ditches connect with the street gutters. The ground under picket lines is crowned and gutters dug, leading to lower ground; otherwise, this ground would become very muddy in wet weather.

DISPOSAL OF REFUSE.

An important consideration in the sanitation of a camp lies in the prompt removal or final disposal of the refuse resulting from its occupation by large numbers of men and animals. This refuse is in three classes, each requiring different treatment. In the order of their importance, these are:

1. Animal wastes.
2. Garbage.
3. Rubbish.

Animal Wastes.

The most dangerous to the health of the camp are the wastes of the human body, and naturally the greatest precautions must be taken to see that these are finally disposed of in a manner which will effectually prevent their ever becoming a source of infection or nuisance.

Disposal of Excreta. Where a system of water carriage can be installed, this method is of course the most desirable. Its layout and operation will differ little from ordinary municipal practice. Such a system will be quite a tax upon the water supply of the camp, as well as a considerable additional expense, and may require treatment works if the discharge is into an inland river. In tidal estuaries or

waters not used for public supplies, these works would not be necessary.

Where the cost would be prohibitive, therefore, or where the water supply is insufficient for water carriage, other systems must be adopted. Various systems of dry sewerage, as the pail system, have been advocated and used to a considerable extent, but are open to many objections, the principal one of which is the hauling or carrying of this matter through the camp. The ground about the pails becomes much polluted, accidents happen in removing them, causing pollution of the ground within the camp, and the final disposal is always a matter of much difficulty.

Burial, dumping into water, and incineration have all been tried and none found entirely satisfactory. The pollution of water supplies and the creation of a breeding place for flies are the main objections. Incineration usually creates an odor, which, while probably not a menace to health, is distinctly disagreeable when carried to camp.

The most satisfactory method has been dumping into large pits, the deposits being covered with crude oil. This prevents odor and keeps flies out. The problem of cartage through the camp, however, and of cleaning the pails, has not been satisfactorily solved, and leads naturally to an inquiry as to the possibility of making the place of deposit the place of final disposal.

The problem is to avoid a nuisance, prevent flies, and to insure a permanent disposal, without danger to health. Various combined latrines and incinerators have been devised to meet this problem, and most of them work very well. They are very bulky to transport, however, most of them require considerable care in setting, all require constant attention in operation, and the resulting odors in camp are far from pleasant.

The proper use of the pit latrine system seems to solve the problem about as well as any other method. In temporary camps, especially those of one night's duration, straddle trenches, about two feet deep, one foot wide and as long as may be required, are constructed upon arrival in camp. To insure their proper use, a shovel is provided and a guard placed to see that all deposits are immediately covered by earth. Such trenches are filled in when the deposits are within a foot of the surface, and their location marked, usually by a large L formed of stones. The nitrifying power of the earth near the surface is well known, and will eventually change the excreta into a harmless substance resembling garden mould, so that this constitutes a true method of disposal, free from nuisance or danger to health.

In more permanent camps, more elaborate methods of keeping out flies are used, and the dry earth covering, which tends to fill the latrine too quickly, may be discarded. The *Havard box,* which fits closely to the ground, stands about twenty inches high, and contains seats with self-closing lids, is placed over a pit about six to eight feet deep, two feet wide and nearly as long as the box. The lids must be hinged to prevent displacement, but a chock or wedge at their back to prevent their opening to a vertical position is a more serviceable device to insure their closing than spring hinges, which break easily. These boxes may be made by the organizations using them, from lumber furnished by the quartermaster. Important accessories are a footboard in front, to prevent caving in the front wall of the pit; urine deflectors, which are pieces of tin (usually from cans rolled out straight), nailed by the upper edges to the inside of the box in front of each seat, and bent into a trough so as to deflect into the pit urine which would otherwise stain the inside of the box; and a

urinal funnel at one or both ends of the box. This latter may be of galvanized iron, or extemporized of tin or tarred paper, and leads into the pit under the edge of the box. About ten seats should be provided for a company latrine.

The tight box was formerly relied upon to keep out flies and to darken the pit so as to discourage their entering it, but as an additional precaution, the box was lifted off each day and the pit burned out by straw and crude oil. Upon the recommendation of one of the regimental surgeons of the New York Division on the Mexican Border, in 1916, a new method was tried out with excellent results.

A thick mixture of lamp black and crude oil or kerosene was prepared and sent around daily to the various camps. The mixture was carried in a barrel mounted upon wheels and provided with a pump and a length of hose. This cart was driven up to each latrine, the contents covered with a layer of the lamp black and oil, and the urinal funnels painted inside with the same preparation. The result was a complete absence of odor and flies, and of the necessity of disturbing the box for burning out the pit.

Such a latrine will serve a company for about three months. When filled to within two feet of the surface, it should be filled in and marked, and the box moved to a new pit.

Waste water from the showers and from washing clothes will run off and gradually be absorbed if the ground slope away from the camp. If allowed to collect in puddles it will breed mosquitoes. Ground upon which soapy water is repeatedly thrown will become foul and ill smelling. A drainage ditch may be dug from the bath to a soakage pit filled with stones, from which absorption will be more rapid than from the surface. When the walls of the pit be-

come clogged with particles of soap, it may be filled in and a new one provided.

Disposal of Manure. Where large bodies of troops are congregated manure collects in such quantities that its disposal becomes a matter attended with great difficulty.

The sanitary regulations prescribe that the ground at all picket lines shall be swept daily and burned off weekly with crude oil. This keeps the ground in very good condition. It is further specified that all straw and manure be hauled away daily to the camp dump. This should be a mile or two to leeward of the camp, considering the prevailing winds. Such swarms of flies always appear in these dumps, however, that the camp is almost certain to be invaded. Burning will prevent breeding of flies, but the odor from the smouldering manure is very disagreeable, and carries for a long distance. Unless there is a steady, favorable wind, there will be a nuisance in camp from the smoke. Crude oil sprinkled over piles of manure will keep flies away, and thus prevent their laying eggs in it, but it will not destroy eggs already laid nor the larvæ that hatch from them.

After the New York Division had been for several months upon the Mexican Border, the neighboring farmers began to awake to the enormous fertilizing value going to waste with the manure, and to haul it away for use on their fields. This, apparently, is the true solution of the problem. In an agricultural country, the farmers will generally be glad to take the manure if their attention is called to its availability. The writer is aware of one case in which a farmer rented his land for a National Guard encampment at a merely nominal fee, upon the condition that all the manure should be left upon his fields.

Garbage.

Kitchen wastes are always great with raw troops. Too much food is prepared by inexperienced cooks, and is often of such unpalatable quality that much of it is left upon the mess pans. An excess of water, also, is used by the kitchen police in cleaning utensils, all of which must be disposed of without nuisance.

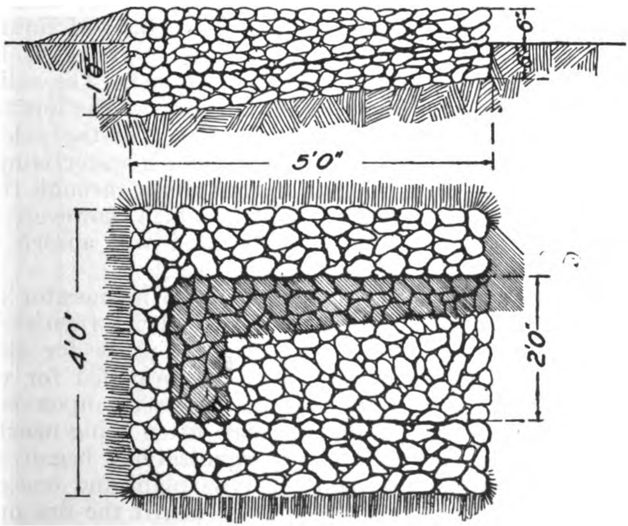


FIG. 124. STONE PIT KITCHEN CREMATORY.

Kitchen water may be allowed to drain into a soakage pit as described for bath water, provided it be first strained through about a six-inch layer of straw, which should be burned and renewed daily or oftener. This prevents the choking and fouling of the pit by particles of grease, soap and other organic matter.

A better method is by evaporation. A *kitchen crematory,* constructed and operated properly, should destroy the garbage of an entire company with little difficulty. Where stones are plentiful, an incinerator of the type shown in Fig. 124 is constructed. A wood fire is kept burning on the stones, and the latter, especially those forming the wall or curb, become heated sufficiently to evaporate liquid wastes if applied gradually. It is said that this device, with a skilled attendant, can evaporate 100 gallons of liquid and incinerate 23 cubic feet of solid garbage in 12 hours, using one-sixth of a cord of wood. The solid matter is placed directly upon the fire and the liquids poured slowly upon the heated stones at the sides. In the ordinary way of using, too much water is applied at once, and much of it runs down through the stones into the bottom of the pit, which, however, is not very objectionable if the ground will absorb it without becoming water-logged.

Where stones are not to be had, an incinerator of the type shown in Fig. 125 is built of brick furnished by the quartermaster. The original plans for this incinerator, as issued to the troops, provided for no fire grate, and the fire was built directly upon the ground under the evaporating pan, often being nearly smothered in ashes. Many organizations began to make improvements upon the type plan, and one of the first of these was a fire grate to lift the fire out of the ashes. This lessened the consumption of fire wood and increased the efficiency of the incinerator. One corporal of Engineers, in charge of the construction of his company incinerator, procured an extra flue and employed it to secure an induced draft, as shown in Fig. 126. The funnel had a lateral swing of nearly 180°, and could be set to catch nearly all the prevailing winds.

In the writer's company the type shown in Fig. 127

was built. The heat from the fire arose around the lower pan and came into contact with the bottom of the upper pan on its way to the flue. Solid garbage was placed on the grate over the fire, and pushed

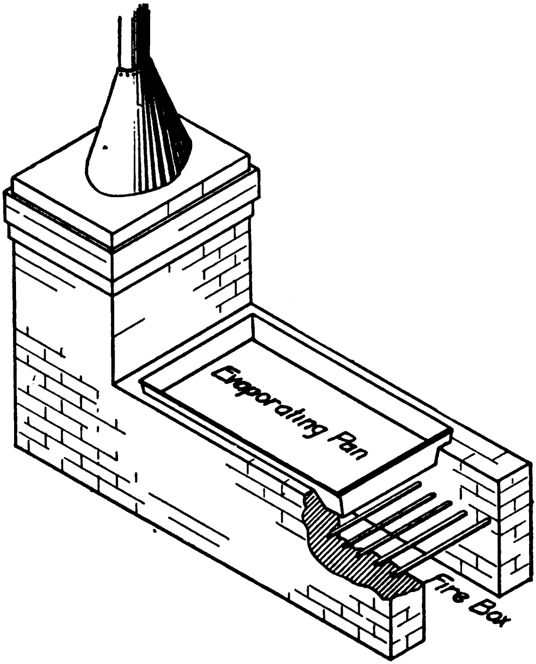


FIG. 125. BRICK INCINERATOR

through into the fire as it dried in the heat. Liquids were poured into the lower pan to be evaporated, and clean water into the upper pan to be heated. A man wishing hot water for washing or shaving could take it from the upper pan, replacing it with an equal

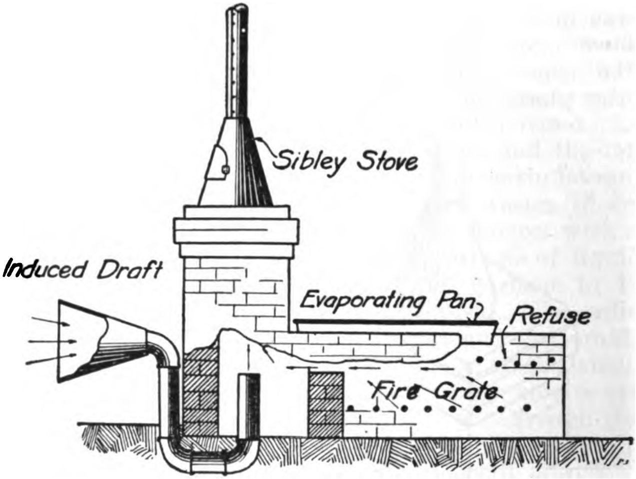
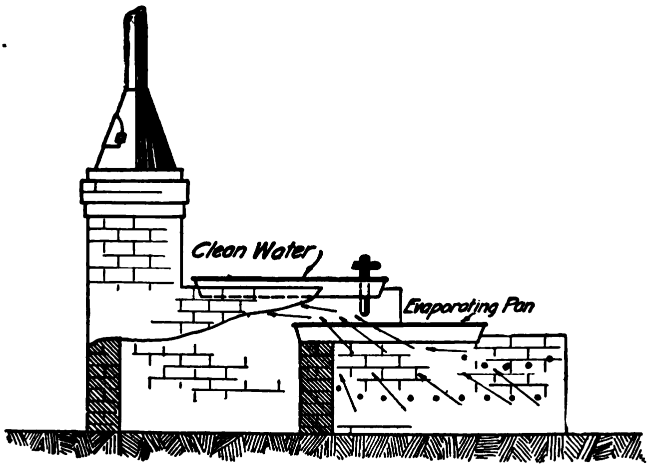


FIG. 126. INCINERATOR WITH INDUCED DRAFT



127. INCINERATOR WITH WATER HEATING PAN

amount of cool water from the tap. The upper pan could be drained for scouring by pulling out the plug. It was found that the liquid garbage could be brought to a boil in forty minutes after lighting the fire, and the whole panful, about 35 gallons, could be evaporated in three hours. The wood consumption was less than the allowance.

The principal difficulty with evaporators of this type lies in the solid garbage which finds its way into the pan from carelessness or as a product of the evaporation. This cakes upon the bottom of the pan, which, when no longer protected by contact with the liquid, burns through and becomes unserviceable. To avoid this, a guard may be placed to enforce proper use of the incinerator, or the attendant may scrape the bottom of the pan with a hoe at intervals. One company covered the pan with a screen, to strain the liquid as it was poured in and to intercept particles of solids.

In a temporary camp construction of this character is impracticable, and garbage cans will probably be used. Liquid garbage will be treated as described before, and the solids will be deposited in a garbage can, which will be taken away daily to a camp incinerator, dump, pit or other place of disposal. These cans should be kept on a framework, off the ground, and must be tightly covered. When returned empty they should be cleaned, scalded and coated with crude oil.

For a camp of only one or two nights' duration, a garbage pit may be dug, covered closely, with an opening for the introduction of the garbage, both solid and liquid. The former soaks into the earth and the latter is covered with earth when the pit is filled in preparatory to leaving camp. A lid must be provided for the opening, to keep out flies, and as an additional precaution the garbage may be kept covered with crude oil.

Rubbish.

Rubbish will accumulate to a great extent about a camp if not properly taken care of. While much of it is of a character not dangerous to health, it is always unsightly, and is liable to engender habits of carelessness in regard to more dangerous wastes if neglected.

Tin cans must be thoroughly burned out, preferably

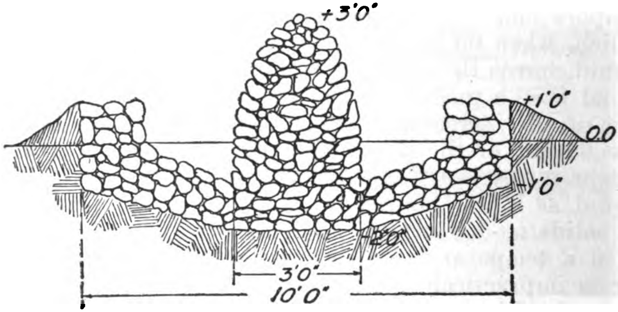


FIG. 128. CAMP INCINERATOR

in the company incinerators, and carefully flattened before being taken to the dump. Otherwise they will hold water after rains and provide breeding places for mosquitoes. Much of the other camp rubbish may be destroyed by burning, and is mostly of a nature to furnish its own fuel. Waste of this character, and even carcasses of animals, may be destroyed in a camp incinerator, which is kept burning continuously, with rubbish for fuel. (Fig. 128.) This is a type, circular in plan and about ten feet in diameter, which has proved very satisfactory in use. The fire is started with brush or fire wood and kept going with rubbish. The central cairn acts as a flue, and the stones be-

come very hot, which assists greatly in destroying liquids or damp substances.

CAMP DISEASES.

Of the epidemic diseases which formerly decimated military camps, most are now well understood as to cause and manner of prevention and may be said to be fairly under control. They may be classified into a number of well defined groups, according to the manner of infection.

Typhoid fever, Paratyphoid A & B, Cholera, and Dysentery are all caused by the introduction of infected food or drink into the alimentary canal. The fly is the principal agent in polluting food supplies. The preventive measures are:

1. Unremitting warfare on the fly, by destruction of his breeding places, by trapping him in kitchens and mess shacks and preventing his access to all food.
2. Protection of food and water from dust.
3. Use of boiled or sterilized water only for drinking.
4. Destruction of all refuse.
5. Avoidance of unauthorized sources of food or drink.

Innoculation against typhoid and paratyphoid has proved very successful, and has practically eradicated the former from army camps. The latter is of comparatively recent origin, and its results are not so well known. Both are now compulsory in the U. S. Army. An innoculation against cholera has also been developed, but is not administered to troops unless in a cholera infested district. Such measures, however, while very efficacious, should not in the least be allowed to take the place of absolute cleanliness in the kitchen and the other precautions named.

Typhus fever and the *Bubonic plague* are transmitted respectively by the bite of the body louse and the rat flea. Preventive measures consist, in the former case, of frequent bathing, disinfection of clothing and avoidance of persons or places liable to be infested with lice, and in the latter case of a war of extermination against rats.

Yellow fever and *Malaria* are caused by the bite of mosquitoes of certain varieties, the *Stegomyia* in the former case and the *Anopheles* in the latter, who have obtained the infection by previously biting patients suffering from these diseases. These mosquitoes are both night biting varieties, so the use of mosquito bars at night is made obligatory upon troops within infected areas. All breeding places of the mosquito, moreover, should be destroyed, tanks covered, cans flattened, puddles filled in and swamps or stagnant pools covered with crude oil. In a malaria country, as an additional precaution, the troops are given a daily dose of about three grains of quinine, the use of which for this purpose is compulsory.

Smallpox, though highly infectious, is well under control, and has been practically eliminated from the army by compulsory vaccination.

Tetanus, or *lockjaw,* is a direct result of the infection of wounds from the soil, and is common in military operations in a highly developed country, as in the invaded portion of France. In going into battle the soldier should be freshly bathed and wear clean underwear, and if wounded should avoid contact between the wound and the soil. In the British army in France, each wounded man is given the tetanus antitoxin as soon as he can be reached. The usual practice is to give two doses, at an interval of seven days. The number of wounded who contract tetanus is now about 2 per 1,000, as compared with an incidence of 32 per 1,000 in October, 1914.

The French and the Germans now follow the same practice, and it is stated that as a result tetanus has practically disappeared from the German army. In the French service it has been determined that in cases where all wounded are innoculated the incidence is 4.18 per 1,000 wounded, and where only the suspicious cases are innoculated, it is 12.79 per 1,000.

Apparently it is not the practice to innoculate all men in the service for tetanus as for typhoid and paratyphoid, although it was so reported early in the war.

Measles, Mumps, Scarlet fever, etc., are commonly brought to camp by recruits who have been exposed before leaving home. They attack particularly troops from rural districts who have not mingled much with others and have not had these diseases in childhood. Prompt isolation and treatment will usually prevent their spreading. Detachments of recruits may be quarantined for about twelve days after arrival.

Venereal Diseases. It is now provided in the U. S. Army that a man exposing himself to venereal disease shall report as soon as practicable to his organization surgeon for prophylactic treatment. This treatment is effective if administered within about eight hours of infection. It is further provided that if he contract a disease and the records show that he has not reported for preventive treatment, he shall be tried for disobedience of orders. In any case, he shall receive no pay while absent from duty.

The ordinary rate of venereal disease in the army used to run as high as 25% of a command. It is now 5% or less.

SANITATION IN THE TRENCHES.

Sanitation in the trenches is a matter of considerable difficulty. Proper living conditions must often be subordinated to a number of other considerations,

and the quarters are crowded, poorly ventilated, damp, and oftentimes downright wet.

General Sanitation.

This corresponds to the sanitation of a camp, and is undertaken for the purpose of securing to the troops occupying the trenches as healthy living conditions as are practicable under the circumstances.

Drainage. The most important contribution to the comfort of the troops in the trenches has to do with drainage, which is usually the most difficult to carry out properly. In wet weather it can never be complete. In laying out a system of deliberate entrenchments, a plan of drainage is always provided, but where tactical considerations have determined the location and arrangement, drainage is often only an afterthought.

All possible precautions should be taken to keep surface water out of the trenches. Where, for purposes of concealment, all parapets are omitted, this is difficult and often impossible. The back edge of every trench should contain a gutter to carry off the water which enters. These gutters lead to low ground though narrow trenches, built with a zig-zag trace to prevent hostile fire through them. Where convenient low ground is lacking, large sump pits may be dug to one side of the trenches and connected with the latter by narrow ditches. The water is bailed or even pumped out of these sumps. All dugouts, trench shelters, bomb proofs, etc., slope slightly to their entrances, where sumps are located. If the soil will not absorb the water which drains into these sumps, they must be bailed out at intervals.

Frequently, with continual passage through the trench, the earth and water are reduced to a thin batter, which will not drain away, and which is as bad to stand in as actual water. This may be pushed

by stable brooms or scoops similar to snow shovels through the trenches and ditches to low ground or sump pits and later bailed out. Sometimes a dam is built between the trench and the sump and the latter filled nearly to the ground surface. Thicker mud is shoveled over the parapet or put into sand bags.

The wider trenches are built, the better the sun and wind can get into them to dry them out, but a wide trench is ordinarily little better than a shell trap, and most troops will endure a little mud to escape the shell fire.

Various devices have been tried to keep the men's feet out of the mud and water. *Floor-boards,* a sort of grating, are made up into about six-foot lengths and sent up from the rear as trench stores. They do very little good when simply laid in the bottom of the trench, as they work down into the mud and conditions are soon as bad as ever. They should be laid upon heavy stakes, driven about three feet into the ground, their tops well above the bottom of the trench. Frequently these gratings are constructed in place upon the stakes, from materials brought up from the rear.

Some trenches are paved with brick, blocks of stone or concrete, with a small ditch along the rear wall. It is said that the Germans use concrete blocks cast especially for this purpose, with a wire loop for handling.

Straw should never be placed in the bottoms of trenches, as it simply tramples down and becomes useless. It also renders the trench more conspicuous to aerial observers. Brushwood is open to the same objection, with the further disadvantage that once trampled into the mud it is practically impossible to dig it out. Bound into fascines, brush makes a very satisfactory footing, and is largely used for the construction of firing steps.

Disposal of Refuse. The long and narrow communications to the rear, constantly crowded with men and materials, greatly increase the difficulty of removing refuse, and emphasize the necessity of keeping down as much as possible the amount to be removed.

Human wastes were formerly removed from the trenches by the pail system exclusively, but this proved unsatisfactory on account of the pollution of the ground about the pails and in the trenches through which they were carried. Deep pit latrines are now used in both the French and British armies. The French make use of a pit covered with boards which are spaced about a foot apart, the intervals serving as straddle trenches.

Lime is the universal disinfectant, and is brought up from the rear in great quantities and used in the trenches and latrines. Crude oil appears to be entirely unknown in sanitation, though much better for this purpose, as it keeps down odors, prevents breeding of flies, which lime will not do, is less bulky and is easy to transport. It is very probable that the U. S. troops will adopt both the Harvard box and crude oil for trench latrines.

There is a great tendency among men in the trenches to throw bits of food, empty cans, rubbish, etc., over the parapet, into sump pits, etc. This must be carefully guarded against, as the resulting odor and flies will become unbearable, especially in hot weather. In the British army the trenches are thoroughly policed daily, and all waste taken back to the destructors in the rear. With the help of crude oil, however, there appears no good reason why garbage alone should not be disposed of in pits similar to the latrines. As there is little cooking in the trenches, the amount of actual garbage should be comparatively small.

Rubbish is properly taken to the rear for incineration. As stations will be fairly permanent during trench warfare, time will be available to construct very efficient types of refuse destructors.

One peculiar feature of the present war is the mortality among rats during a gas attack. The trenches are always infested with rats, and the poisonous gas, being heavier than air, settles into their holes and kills them. To avoid a nuisance, the carcasses must be sought out and disposed of after each attack by gas.

Personal Hygiene.

Care of feet. The worst evil in trench life is wet clothing, particularly on the feet. The immediate results of standing in water or mud or of wearing wet shoes and socks are *trench feet* and, in cold weather, *frost bite.* The latter was very common in the British army during the first winter in the trenches, until it was finally decided that the men themselves were to blame, in neglecting to change to dry socks when the opportunity afforded, in wearing tight puttees, which hindered the circulation, etc. Men who reported with frost-bitten feet were therefore court-martialed, and an immediate improvement was noticed.

Trench feet result from continuously wet feet, and may be avoided by proper care. Rubber boots are now issued to men going into the trenches, but care must be taken that they are not worn more than necessary, as they make the feet tender and more susceptible to ailments. Each man going into the trenches bathes and rubs his feet and legs with whale oil. He also carries an extra pair of dry socks. The wet socks are taken to the rear each night, dried, and returned the following night.

If the feet are washed in the trenches, it is important that no hot water be used, nor should the feet

be dried near a fire, as they are thus made tender and more subject to frost-bite. They should be washed in cool water and *rubbed* dry, to stimulate the circulation.

Drinking Water. After a trial at boiling water for use in the trenches, both the French and British have adopted the method of sterilization by hypochlorite of lime. The treated water is piped into the trenches if practicable, otherwise it is brought up in wheeled tanks. Men should be restrained from drinking water taken from the trenches or from shell holes, even if boiled.

Vermin. It is practicably impossible, under present conditions, to avoid vermin in the trenches. However careful a man may be, he is always associated with others not so careful, or his organization may take over a trench which is infested with lice from previous occupants. It is said that a certain kind of underwear will keep vermin from the body, and various insect powders are in common use, with more or less success. Short hair and absolute personal cleanliness are the best preventive measures.

Once infested, the hair on various parts of the body should be cut short and a bath taken in gasoline or kerosene. Upon coming from the trenches, troops are marched to the baths, where they cleanse themselves thoroughly while their clothing is being cleaned and baked. Just before returning to the trenches, this operation is repeated. In the trenches themselves lime is used freely, shelters are whitewashed and the straw in dugouts is frequently renewed, the old straw being burned.

With all these precautions, vermin still persist, principally on account of the carelessness of some of the men, and they will probably continue to infest the trenches until the appearance of typhus fever causes energetic measures for their eradication.

CHAPTER XIX.

CONCLUSION.

The foregoing chapters have presented a very incomplete outline of some of the engineering duties and a few of the military duties which will devolve upon the company officer in time of war. These subjects are large, and have barely been touched upon in this discussion, and there are others which have not even been mentioned. Nothing has been said upon the subject of infantry tactics, which will probably occupy as much of an officer's time as the technical work. Similarly, no mention has been made of the services of security and information, with their sub-divisions of outposts, advance and rear guards, patroling, etc.

Transportation and supply, though vital to the existence of the army and introducing many intricate problems, have been omitted, as have the subjects of military law and government.

Coming down to the field of engineering itself, there will be found no mention of railways, the very arteries of an army, though not every engineer knows how all ideas of maximum gradients or curvature are discarded in military practice, or that the usual gage of a military railway is made 4 feet 9 inches, to allow for irregularities of track laying.

All these are beyond the scope of a work of this character, which aims to point out the way to the engineer, not to instruct him. It is hoped, however, that the material presented will give an idea of the magnitude of the problems which will confront engineers in war and point out the necessity of individual preparation. The army which will be required by the

United States to bring the present war to a successful conclusion is estimated by one of our foremost military authorities at 2,500,000 men. Nearly as many more will probably be called to the colors and placed in training as a reserve force. In the Civil War we called out two million and a half men, and that was before the days of large armies. With 2,500,000 men we should need about 120,000 engineers, of whom 4,000 would be officers and 24,000 non-commissioned officers. The latter are as important to the army as the officers, and particularly so in the Engineers. No man should hold a corporal's warrant who is not fully capable of performing the duties of a foreman of construction on civil works, and the grade of sergeant requires a man competent to fill the position of overseer or superintendent on a construction job. Every engineer must not think that his civilian training would in itself entitle him to a commission. Many who entertain this view might find it difficult to hold down a sergeant's job. It is, however, within the reach of every technically trained man to qualify himself for a commission, and those who do not are contributing to the shortage of officers which is bound to occur, as well as depriving themselves of a military position on a par with their education and social connections. First-class privates of engineers are skilled workmen: carpenters, blacksmiths, machinists, riggers, electricians and mechanics of all kinds. Technical men can even find a place in their ranks as sketchers, surveyors, etc. Privates are of the class of outdoor workmen met on civil works. Lumbermen, miners, boatmen, teamsters, chauffeurs and laborers are fair examples of men useful in the Engineers. The lines between the two grades of privates are not closely drawn, and length of service, or special experience and adaptability may advance a man from one grade to the other.

It is probable that many Engineers must serve in the ranks as privates or non-commissioned officers. There is no disgrace in such service. The best citizens of Europe have been doing this for three years, and there is no reason why Americans should be exempt. A company commander respects and relies upon an efficient and dependable non-commissioned officer as much or more than upon his subaltern officers. Many of the sergeants of the U. S. Engineers have a reputation throughout the Army for their engineering skill, and their practical knowledge of the details of the engineer soldier's work is probably in excess of that of many officers. It means something to be a sergeant in the Engineers.

But all cannot be privates, corporals or sergeants. There will be urgently needed about 4,000 officers, and the Engineers of this country must furnish them. The Regular Army, National Guard, Training Camps and Officers' Reserve Corps may supply enough to officer the troops which take the field at the beginning, but as the more experienced officers go to the front there will be less and less opportunity for men with little or no military training to fit into an organization and learn by absorption. Future levies of troops will be more and more officered by men of no practical experience, and will therefore take longer to train or will go to the front less thoroughly trained.

Technical men sufficiently trained to replace losses among the officers will be hard to find, and the standard of the commissioned personnel will suffer. One cannot step from civil life into a commission and hope to successfully lead engineer troops in the field. Men are quick to detect uncertainty or hesitation in an officer, as a horse recognizes lack of confidence on the part of his rider, and to lose faith in their leader is the first step towards the complete disorganization of troops.

General Morrison, author of "Minor Tactics" and "Infantry Training," says:

"The responsibility resting upon an officer in time of war is great. His mistakes are paid for in blood. To seek a command in war beyond his capabilities is no less criminal than for a man with no knowledge of a locomotive or railroading to attempt running the engine of a crowded express train on a busy line."

The one great source of officers after hostilities commence must be the field forces, particularly to make up losses among the commissioned personnel. The training is intensive in a high degree, and directly in line with the service required. As the war progresses this source of supply will be drawn upon to a greater and greater extent, until practically all original appointments will be from the ranks.

This will be done for two reasons: *First,* the training that can be had at the front under service conditions is so much better than can be given in a school or training camp, and the latter can be so much better given to selected men who have served at the front and have been recommended for commissions.

Second, the training camps are filled by volunteers, for a preferred service perhaps, but volunteers no less. The volunteer system has always broken down in long wars, and the supply, even for officers, will not last indefinitely in this.

It may be safely stated, therefore, that every qualified man will receive a commission, whether it be by way of the officers' training corps or through the ranks.

In fact, the writer confidently expects to see the day when practically all candidates for commissions will be men who have served at the front and have been recommended for an officers' training course.

There should be no hesitation on the part of an engineer who has failed to make the training camps, therefore, in entering the ranks to work for his commission. For the young technical man who has the education, the physique and the energy to succeed as an officer, there can be no more patriotic act than enlistment in the Engineers. Such a man, with his mind set upon learning all that pertains to his branch of the service, simply cannot be kept down.

This war is one of engineers, and upon the efficient leadership of our engineer troops will depend in large measure our ultimate success.

THE END

APPENDIX I.

The following is a list of reading upon military subjects recommended by the Chief of Engineers, U. S. Army, for the use of civilian engineers:

WAR DEPARTMENT

OFFICE OF THE CHIEF OF ENGINEERS

Washington, November 27, 1915

Military Reading for Civilian Engineers.

By authority of the Secretary of War, and in response to frequent requests, the following suggested list of reading is published for the information of civilian engineers desiring to inform themselves on military subjects.

These references have been selected, first, with a view to giving the engineers unfamiliar with the art of war, a general survey of that subject—an understanding of which is the first essential to insure successful application of engineering knowledge and resources to military purposes; and, second, with a view to setting forth, as far as practicable, the ways in which engineering is applied to military purposes and the means provided therefor.

Both military art and military engineering are progressive, and a considerable part of the latest and most detailed information published is available only in service journals of our own and foreign armies. This is particularly true of technical details of seacoast defense (including submarine mining), of field artillery, of military aviation, and the influence of these on military engineering. It is believed, however, that the fundamentals of each subject are well covered by the

references given in this list. While the list is long, the relative importance of the various works is indicated, and suitable comments on each are included, so that persons using the lists of references may be able to select those which particularly interest them.

The references under each subject are generally divided into two groups, the first containing the more essential references, and the second those suitable for persons desiring to inquire further into the subject.

Suggestions looking to improvements of the lists will be gladly received.

Note—The following abbreviations are used:

Supt. of Docs.—Superintendent of Documents, Government Printing Office, Washington, D. C.

Book Dept.—Book Department, Army Service Schools, Fort Leavenworth, Kans.

"A" MILITARY POLICY, CONDUCT OF WAR, AND MILITARY HISTORY.

Group I.

(1) Official Bulletin, Vol. I, No. 2, Office of the Chief of Staff, Washington, D. C.
(Especially pp. 21-39) Publisher: Army War College, Washington, D. C. Free.
(An official outline of the theory under which our forces are to be organized and administered.)

(2) Military Policy of the United States—Upton. May be obtained from Supt. of Docs.; paper, 50 cents; cloth, 65 cents.
(A most valuable and comprehensive review of this subject.)

(3) Field Service Regulations, 1914. May be obtained from Supt. of Docs.; 60 cents.
(A condensed official statement of principles, methods and details of military operations.)

(4) Elements of Strategy—Fiebeger. Publisher, U. S. Military Academy, West Point, N. Y. May be obtained from Book Dept.; 75 cents.
(A short outline, with historical illustrations.)

GROUP II.

(5) Conduct of War—Von der Goltz; translated by J. Dickman; Hudson Publishing Co., Kansas City, Mo. May be obtained from Book Dept.; $1.70.

(The standard work on this subject, covering generally the same ground as (4), but more abstractedly and elaborately.)

(6) On War—Clausewitz; translated by J. J. Graham; 3 vols.; K. Paul, Trench, Trubner & Co., 1908. May be obtained from Book Dept.; $6.60 (including postage and duty.)

(The greatest classic on the subject; a complete analysis of the phenomenon of war, and profound discussion of the mechanism thereof. Written early in the 19th Century, it is still the foundation of modern military theory.)

(6½) The Nation in Arms—Von der Goltz. May be obtained from Book Dept.; $2.50.

(An excellent modern work on war; less elaborate but more readable than Clausewitz.)

(7) American Campaigns—M. F. Steel; 2 vols.; Publishers: Byron S. Adams Publishing Co., Washington, D. C. May be obtained from Book Dept.; $4.50.

(In addition to careful historical surveys of all the campaigns from the Colonial Wars to the Spanish-American War, these lectures give extensive and valuable comments as to the military principles.)

(8) A study of Attacks on Fortified Harbors—Rodgers; Proceedings Nos. 111, 112 and 113, U. S. Naval Institute, Annapolis, Md.

(9) Lessons of the War with Spain—Mahan. Publishers: Little, Brown & Co., Boston, Mass. May be obtained from Book Dept.; $2.00.

(Of special importance, as showing the true relation between our coast defense and our navy).

(10) Reports of Military Observers on the Russo-Japanese War. Part III—J. E. Kuhn. May be obtained from Supt. of Docs.; 60 cents.

(In addition to an account of operations, this report contains valuable information as to fortification and siege work, organization and equipment.)

(11) Organization and Operation of the Lines of Communications in War—Furse, 1894. Publishers: Wm. Clowes & Sons., Ltd., London.

(An old but comprehensive survey of this subject, with much historical information.)

"B" PERMANENT FORTIFICATIONS.

Group I.

(The references given cover chiefly the principles and general features of this subject; the *details* are mostly printed in unavailable form, either in service journals or in confidential documents. References to some of the former can be furnished, if desired.)

(12) Report of National Coast Defense—(Taft) Board, 1906. May be obtained from Army War College, Washington, D. C. Free.

(The official project for harbor defenses of the United States. On account of progressive obsolescence of seacoast defenses, this project has been or is being, modified, but still sets forth clearly the fundamentals of its subject.)

Group II.

(13) Lectures on Seacoast Defense—Winslow. Publishers U. S. Engineer School, Washington Barracks, D. C. Price 50 cents.

(Much of these lectures relates to technical details, and a considerable part is now obsolete.)

(14) Permanent Fortifications—Fieberger, 1900; U. S. Military Academy, West Point, N. Y.; $1.00. May be obtained from Book Dept.

(While rather old, this work gives a simple presentation of the fundamentals on its subject, including an historical outline. A revised edition will soon be published.)

(15) Fortifications—C. S. Clarke; Dutton & Co., New York; $4.50. May be obtained from Book Dept.

(A treatise on the same lines as (14)).

(16) Principles of Land Defense—Thuillier, 1902; Longmans, Green & Co. May be obtained from Book Dept.; $3.83.

(A very valuable work, covering the principles of both field and permanent fortification.)

"C" ORGANIZATION, EQUIPMENT AND DUTIES OF ENGINEER TROOPS.

Group I.

(17) Field Service Regulations, 1914. (See "A" 3.)

(18) Tables of Organization, 1914. May be obtained from Supt. of Docs.; 25 cents.

(These tables represent—subject to modification and

within the limits of existing law—the approved policy of the War Department with regard to organization.)

(19) Official Bulletin, Office of the Chief of Staff, vol. I, No. 4 (Appendix 4). Use of Engineer Troops. Publisher: Army War College, Washington, D. C. Free.
(An official statement of the principles which should govern in the use of engineers, with practical suggestions.)

(20) Duties of Engineer Troops in a General Engagement of a Mixed Force—Burgess. Publishers: U. S. Engineer School, Washington Barracks, D. C.; 25 cents.
(Obsolete in some respects, particularly organization, but excellent in general scope.)

(21) General Orders No. 6, War Department, 1915. May be obtained from The Adjutant General, U. S. Army, Washington, D. C. Free.
(Prescribes the training of Engineer troops.)

GROUP II.

(22) Studies in Minor Tactics—Army Service Schools, 1915. May be obtained from Book Dept.; 50 cents.
(The principles of Minor Tactics are set forth by solution of a series of problems.)

(23) Technique of Modern Tactics—Bond & McDonough, 1914; Banta Publishing Co., Manasha, Wis. May be obtained from Book Dept.; $2.55.
(This work covers, in a very specific way, the principles of tactics for all arms, a general knowledge of which is essential for engineers.)

(24) Operation Orders—Von Kiesling; translation. May be obtained from Book Dept.; 50 cents.
(A lucid exposition, by use of assumed cases, of the operation of highly trained troops of all arms in various phases of battle.)

(25) Engineer Unit Accountability Manual. May be obtained from Supt. of Docs.; 5 cents.
(Official lists of standard equipment supplied to Engineer battalions and companies.)

(26) Organization of the Bridge Equipage of the U. S. Army, 1915 (Revised edition just going to press.)
(Includes description of equipage and regulations for ponton drill.)

(27) Officers' Manual—Moss; Banta Publishing Co., Menasha, Wis.; $2.50. May be obtained from Book Dept.
(Treats of routine duties of officers, customs of the service, army organization, etc.)

(28) Manual for Courts Martial. May be obtained from Supt. of Docs.; 50 cents.

"D" FIELD ENGINEERING.

(Military field engineering at the front differs from ordinary engineering work in the field, in being generally simpler, of a rough-and-ready character, and especially because of the limited equipment which can be taken along with the advance of an army, and because of the necessity of working in strict subordination to the military situation. In rear of the army, on the contrary, conditions are very similar to those governing ordinary engineering operations, and civilian organization is suitable, subject to directions by the higher military staff. Little attempt is made in works on military field engineering to treat of general engineering methods.)

(29) Field Fortifications—Fiebeger, 1913; John Wiley & Sons, New York. May be obtained from Book Dept.; $1.90.
(In addition to technical details, this work gives valuable historical illustrations of the principles of this subject.)

(30) Field Entrenchments, Spade work for Riflemen—John Murray, London. May be obtained from Book Dept.; 40 cents.
(A very up-to-date little work, especially on details.)

(31) Notes on Field Fortification—Army Field Engineer School. May be obtained from Book Dept.; 30 cents.

(32) Engineer Field Manual—Professional Papers No. 29, Corps of Engineers, U. S. Army, 3d edition, 1909, 500 pages. May be obtained from Supt. of Docs., $1.00.
(A very complete official pocketbook for Engineer officers in the field, containing much tabular and technical data, as well as brief outlines of principles and methods. The subjects covered are: Part I, Reconnaissance; Part II, Bridges; Part III, Roads; Part IV, Railroads; Part V, Field Fortification, and Part VI, Animal Transportation. A new revision of the manual is contemplated, but will not be ready within a year. The portion of the manual relating to Field Fortifications, being

somewhat obsolete, should be considered in connection with either (30) and (31) above. The portion relating to Railroads is largely superseded by (35) below.)

(33) Notes on Bridges and Bridging—Spalding. May be obtained from Book Dept.
(A small pamphlet on military bridging.)

(34) Military Topography for Mobile Forces—Sherrill, 2d edition; Banta Publishing Co., Menasha, Wis, 1911. May be obtained from Book Dept.; $2.25.
(Besides matter given in ordinary text-books on surveying, this work gives in detail the special methods of sketching developed in the army for rapid military mapping.)

(35) Military Railroads—Connor; Professional Papers No. 32, Corps of Engineers, U. S. Army. Supt. of Docs.; 50 cents.
(Intended to cover general administration of existing railroads for military purposes and the handling of railroads by military personnel in the advanced sections where railroads can not be operated by their regular civilian organizations, or where new railroads are required in the immediate vicinity of the Army. Revised edition soon to appear.)

(36) Notes on Military Explosives—Weaver; J. Wiley & Sons, New York; 1912. May be obtained from Book Dept.; $2.20.
(Elementary notes on this subject will be found in the Engineer Field Manual and other references cited. The work is more elaborate.)

"E" MISCELLANEOUS.

(37) Regulations for the Army of the United States; Supt. of Docs.; 50 cents.

(38) The "Volunteer Law," approved April 25, 1914; Bulletin No. 17, War Department, 1914. May be obtained from The Adjutant General, U. S. Army, Washington, D. C. Free.

(39) General Orders No. 54, War Department, 1914. May be obtained from The Adjutant General, U. S. Army, Washington, D. C. Free.
(Covers examination of candidates for commissions as officers of *volunteers*.)

(40) General Orders No. 50, War Department, 1915. May be obtained from The Adjutant General, U. S. Army, Washington, D. C. Free.

(Amends General Orders 54, 1914, as to examination of candidates for commissions in volunteer *engineers.*)

(41) Treatise on Military Law—Davis; J. Wiley & Sons, New York. May be obtained from Book Dept.; $5.30.

(42) Elements of Military Hygiene—Ashburne; new edition; Houghton, Mifflin & Co., Boston, 1915. May be obtained from Book Dept.; $1.30.

"F" PERIODICALS.

(43) Professional Memoirs, Corps of Engineers, U. S. A., and Engineer Department at Large; Bi-monthly (formerly quarterly); Washington Barracks, D. C., Engineer Press; per year, $3.00.

(44) The Royal Engineers' Journal—Royal Engineers' Institute, Chatham, England; Monthly; per year, $4.00. (American agents, E. Steiger & Co., 49 Murray St., New York).

(45) Journal of the Military Service Institution, Governors Island, New York. Bi-monthly; published by the Institution; per year, $3.00.

(46) Journal of the United States Artillery; Bi-monthly; Fort Monroe, Va.; Coast Artillery School press; per year, $2.75, including Index to Current Literature; without Index, $2.50.

(47) Journal of the United States Cavalry Association; published by the Association at Fort Leavenworth, Kans.; per year $2.50.

(48) Infantry Journal; Bi-monthly; published by the U. S. Infantry Association, Union Trust Building, Washington, D. C.; per year $3.00.

(49) Field Artillery Journal; quarterly; published by the U. S. Field Artillery Association, 601 *Star* Building, Washington, D. C.; per year $3.00.

APPENDIX II.

Equipment of Engineer Troops

The following are the principal elements of the wagon and pack loads of the engineer combat train. For full detailed lists the Unit Accountability Equipment Manuals should be consulted.

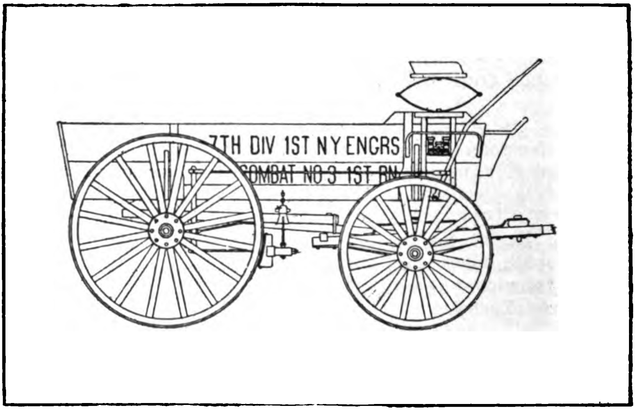


Fig. 129. Headquarters Tool Wagon, Escort Type.

1. LOADINGS OF HEADQUARTERS TOOL WAGONS, ESCORT-WAGON TYPE.

	Engineer regiment.		Mounted engineers, battalion headquarters.
	Regimental headquarters.	Battalion headquarters.	
Blacksmith equipment:			
Anvil, B. S., 100 pounds, with B. S. apron, coal bags, chisels, clinch cutter, clinching iron, countersink, flatter, 2 inches; fullers, T and B, 3/8-inch; hammers (7); hardy; heading tools, 1/2, 3/4, and 1 inch; rivet headers, 1/2, 3/4, and 1 inch; punches, 3/8 and 3/4 inch; swedges, T and B, 1/4, 1/2, 3/4, and 1 inch; and tongs	....	1	1
Brace, ratchet, and set of 13 drills (range of sizes) 5/32 to 15/32 by thirty-seconds, 9/16 to 3/4 by sixteenths	....	1	1
Files, assorted, 8 to 16 inches	....	10	10

LOADINGS OF HEADQUARTERS TOOL WAGONS, ESCORT-WAGON TYPE—Continued.

	Engineer regiment.		Mounted engineers, battalion headquarters.
	Regimental headquarters.	Battalion headquarters.	
Forge, portable, with rake and shovel	....	1	1
Hammer, sledge, 10 pounds	....	1	1
Handles, assorted	....	10	10
Oiler, ½ pint	....	1	1
Pipe cutter, No. 2 (size, ½ to 2 inches)	....	1	1
Rule, 2-foot folding	....	1	1
Shoeing outfit, including shoeing knives, toe knives, nippers, pinchers, rasp, and tongs	....	1	1
Stocks, dies and taps, No. 2, sets (size, ½ to 1¼ inches by eighths)	....	1	1
Tire measure	....	1	1
Vises, B. S., 4-inch jaws	....	1	1
Wrench, monkey	....	1	1
Blacksmith supplies, sets, consisting of—			
Borax, 5 pounds; coal, blacksmith's, 4 bushels; nails, horseshoe, 25 pounds; nuts, assorted, 40 pounds (sizes, ⅜, ½, ¾, and 1 inch); oil, machine, 1 quart; steel, soft, bars, 156 feet (sizes, ½ by 1 inch and 2 inches; ¾ by 1¼ inch and 2 inches; 1 by 2 inches, and ½, ¾, and 1 inch round); steel, tool, 5 feet (size, ¾-inch octagon)	....	1	1
Map reproduction equipment:			
Buckets, galvanized iron (capacity, 14 quarts)	3	....	....
Cans, galvanized iron, 5 gallons	2	....	....
Cans, galvanized iron, 3 gallons	1	....	....
Chests, zincographic (sets of 3) for prints 24 by 30 inches, with suitable bottles, bowls, brushes, glazed rollers, knives, needles, zinc plates (16), press (hand), roller grip, rollers (leather), snakestone, sponges, trays (20 by 24 inches), and whirler	1	....	....
Frames, blue print, 24 by 30 inches, with tray (24 by 39 inches) and tin tubes (2)	1	....	....
Instruments, drawing, lithographic, sets, with triangles and "T" square	1	....	....
Lanterns, Dietz	2	....	....
Screw drivers (3-inch blade)	1	....	....
Shears, 16-inch	1	....	....
Stoves, oil, single burner	1	....	....
Tents, hospital, with shield, complete	1	....	....
Towels, bath	4	....	....
Wrench, monkey, 12-inch	1	....	....
Zincographic outfit supplies, sets, for cleaning zinc plates: Nitric acid, 5 pounds; flash, 12 cans; pumice, 5 pounds; caustic soda, 10 pounds. For photographic transfer: Brown print paper, 30-inch, 10 yards; chromic, 2 pounds; phosphoric, 2 pounds; and tannic, 1 pound; albumen, 2 pounds; ammonium bichromate, 1 pound; ab-			

LOADINGS OF HEADQUARTERS TOOL WAGONS, ESCORT-WAGON TYPE—Continued.

	Engineer regiment.		Mounted engineers, battalion headquarters.
	Regimental headquarters.	Battalion headquarters.	
sorbent cotton, 3 pounds. For direct transfer process: Autographic paper, 17 by 20 inches, 2 gross; touche, 4 ounces; autographic ink, 6 ounces. For etching and retouching plates: Chromic, phosphoric, tannic acids; alum, powdered, 2 pounds; asphaltum, 1 pound; lavender oil, 1 ounce; olive oil, ½ pint; banana oil, 8 ounces; beeswax; dragon's blood, 1 pound; gum arabic, 25 pounds; etching ink, 1 pound; willow charcoal, 1 pound; etching slips; resin powder, 2 pounds; tallow, 4 ounces; turpentine, 3 gallons. For printing and drying: Book paper, 19 by 24 inches, 5 reams; blotting paper, 19 by 24 inches, 6 dozen; cheesecloth, white, 300 yards; hand-press ink, 3 pounds; turpentine. Miscellaneous: Coal oil, 10 gallons; thumb tacks, 2 dozen; varnish, 1 pint; lantern and oil-stove wicks. Blue-print outfit: Blue-print paper, 30-inch, 50 yards, 1 roll.	1	....	....
Pioneer outfit: Screw jacks	....	2	....
Army-wagon parts, extra (furnished by the Engineer Department):			
Blocks, brake	2	2	2
Bolts, assorted, sets, king, 1 by 18 inches (1); tire, ¾ by 2¾ inches (1), ¾ by 3 inches (5); wagon, ¼ by 1½ inches (2), $\frac{5}{16}$ by 1¾ inches (2), $\frac{5}{16}$ by 2 inches (1), $\frac{5}{16}$ by 2½ inches (2), ⅜ by 3 inches (2), ½ by 11 inches (1), ⅝ by 4 inches (4)	1	1	1
Links, open	3	3	3
Nuts, axle (1 R. H. and 1 L. H.)	2	2	2
Rivets, iron, $\frac{5}{16}$ by 1½ inches (6), ¼ by 1½ inches (4)	10	10	10
Tongue, reach, doubletree, single tree (of each)	1	1	1
Army-wagon accessories (furnished by the Quartermaster Corps):			
Currycomb, horse brush, whip, and bucket, G. I. (of each)	1	1	1
Grease, axle, pounds	4	4	4
Nose bags, halter with strap (of each)	4	4	4
Army-wagon harness parts, extra (furnished by the Quartermaster Corps):			
Buckles, ¾, ⅞, 1, and 2 inch (1 of each)	4	4	4
Clips, trace	2	2	2
Hames	2	2	2
Rings, ¾, 1, 1½, and 2 inch (1 of each)	4	4	4
Snaps, 1, 1¼, and 2 inch (1 of each)	3	3	3
Straps, hame	3	3	3

LOADINGS OF HEADQUARTERS TOOL WAGONS, ESCORT-WAGON TYPE—Continued.

	Engineer regiment.		Mounted engineers, battalion headquarters.
	Regimental headquarters.	Battalion headquarters.	
Army-wagon harness accessories and supplies (furnished by the Quartermaster Corps):			
Oil, neat's-foot, gallon	½	½	½
Shoes, mule, fitted with 8 nails each	16	16	16
Soap, harness, pounds	1	1	1
Sponge	1	1	1
Wire, stove, spool	1	1	1

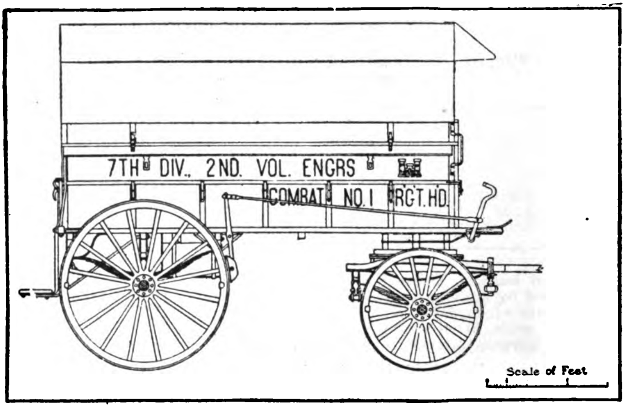


FIG. 130. SPRING TOOL WAGON.

2. LOADINGS OF HEADQUARTERS TOOL WAGONS—SPRING.

	Engineer regiment.		Mounted engineers, battalion headquarters.
	Regimental headquarters.	Battalion headquarters.	
Drafting equipment:			
Board, drawing, 31 by 42 inches, with trestle, with the following equipment: Office set drawing instruments; proportional dividers; steel eraser, erasing shield; map measure; protractor, 8-inch, G. S., in case; scale, 12-inch, engineer; scale, 12-inch, architect; slab, ink; slide rule, 16-inch; T square, 42-inch; triangle, 30°–60°, 10-inch; triangle, 45°, 8-inch............sets	2	....	2
Lamps, acetylene....................	2	....	2
Pantograph..........................	1	....	1
Tent, hospital, regulation, with shield, complete..........................	1	....	1
Tubes, tin..........................	4	....	4
Drafting supplies:			
Books, note (3); erasers, rubber (3); ink, drawing, bottles, black (2), blue (1), brown (1), carmine (1); ink, india, 1 stick; paper, blotting, $3\frac{3}{4}$ by $9\frac{1}{2}$ inches, 1 dozen; cross-section, 20-inch, 5 yards; drawing, 30-inch, 30 yards; wrapping, 40 by 48 inches, sheets, 2 dozen; pens, crow-quill, dozen, with holder (1), mapping, dozen, with holder (1); pencils, drawing, H. 3H, and 5H (1			

LOADINGS OF HEADQUARTERS TOOL WAGONS—SPRING—Continued.

	Engineer regiment.		Mounted engineers, battalion headquarters.
	Regimental headquarters.	Battalion headquarters.	
dozen each); pencil pointing pad (1), scratch (2); thumb tacks, 3 dozen; tracing cloth, 30-inch, 24 yards.............sets	2	....	2
And the following miscellaneous supplies:			
Paste, library..........................	1	....	1
Pins, cones..........................	1	....	1
Tape, adhesive, rolls....................	4	....	4
Twine, hemp, 2-ounce ball................	2	....	2
Miscellaneous equipment:			
Manuals, Engineer Field.................	2	....	2
Padlocks, brass........................	5	....	5
Photographic equipment: Camera, 3A Graflex, with folding tripod (Crown No. 2)..........	1	....	1
And the following accessories: Agate trays (4); bath towels (4); canvas buckets (2); chamois skin; duplicating tanks, set; film tank; graduate, 8-ounce; photographer's manual; printing frames, 5 to 7 inches (2); rubber blankets (2); ruby lamp; shears, 8-inch; spotting brush; stirring rods (2); thermometer....set	1	....	1
Photographic supplies:			
Developer, M. Q. and Pyro, tank, boxes of each..............................	15	....	15
Films, 3A, 6 exposure....................	48	....	48
Hypo acid, ½-pound boxes................	48	....	48
Paper, developing, 3A size, gross..........	3	....	3
And the following: Absorbent cotton; alcohol, denatured, 1 pint; cheesecloth, white, 3 yards; film albums, 3A size (2); formaline, 1 pound, intensifier, 6 tubes; opaque, 1 tube; photo clips (24); photo notebooks (2); potassium bromide, tabloid, 6 tubes; pushpins (24); twine, hemp, 1 ball; wicks for ruby lamp (6)..................................set	1	....	1
Reconnaissance equipment:			
Chests, sketching outfit, each containing: pace tally; pencil pocket; rectangular protractor; service clinometer; sketching board, with alidade and folding tripod; timing pad holder....................	3	....	3
And the following additional equipment—			
Barometers, aneroid, with cases........	2	....	2
Clinometers, service, with case.........	4	....	4
Compasses, box (2), prismatic with case (2), watch (6)....................	10	....	10
Odometers, with cases................	2	....	2
Pace tallies..........................	4	....	4
Protractor, rectangular................	1	....	1
Reconnaissance supplies:			
Books, field note........................	16	....	16
Celluloid, sheets........................	36	....	36
Erasers, rubber, pencil..................	14	....	14

LOADINGS OF HEADQUARTERS TOOL WAGONS—SPRING—Continued.

	Engineer regiment.		Mounted engineers, battalion headquarters.
	Regimental headquarters.	Battalion headquarters.	
Pads, timing	18	....	18
Paper, sketching, sheets, gross	1½	....	1½
Pencils, drawing, H (42), blue (14), red (14), green (14)	84	....	84
Protectors, pencil-point	14	....	14
Tape, adhesive, rolls	6	....	6
Surveying equipment:			
Boards, stadia	6	....	2
Field glasses, with case	1	....	1
Levels, engineer's, and tripods	2	....	1
Plane tables, complete, and tripods	1	....	....
Repair kit for steel tapes	1	....	1
Rods, level, Philadelphia	4	....	2
Slide rule, 16-inch, with case	1	....	....
Stadia computer	3	....	1
Tapes, steel, 100-foot	2	....	1
Transits and tripods	2	....	1
Surveying supplies:			
Books, level	4	....	2
Books, transit	6	....	2
Cloth, signal, red and white, yards (of each)	30	....	15
Paper, plane table, sheets, dozens	2	....	....
Spring tool-wagon parts, extra (furnished by the Engineer Department):			
Bolts, one each except where shown—¼-inch carriage, 1½, 1¾, 2½, 2¾ inch; 3/16-inch carriage, 1½ inch (2), 2¼ inch; 5/16-inch carriage, 2, 2½, 3 inch (2); ⅜-inch carriage, 3½, 4, 5½, 6 inch; king, ¾ by 12 inches; machine, 7/16 by 2¼ inches; ¼-inch tire, 2 inch (2), 2½ inch (4); 5/16-inch tire, 1¾, 2½ inch; ⅜-inch tire, 4½, 5½, 6 inch ... set	1	....	1
Brake, block	1	....	1
Links, open	3	....	3
Nuts, axle (1 each R. H. and L. H.)	2	....	2
Rivets, iron, ¼ by 1¼ inches	2	....	2
Rivets, iron ¼ by 2½ inches	3	....	3
Screws, wood, flathead, No. 12, 1½ inch	2	....	2
Screws, rivet head, No. 9, 1¼ inch	3	....	3
Singletree	1	....	1
Tongue	1	....	1
Spring tool-wagon accessories (furnished by the Quartermaster Corps):			
Bucket, G. I., currycomb, horse brush, monkey wrench, and whip (of each)	1	....	1
Grease, axle, pounds	1	....	1
Halter, with strap, and nose bags	4	....	4
Harness parts, extra (furnished by the Quartermaster Corps):			
Buckles, ¾, ⅞, 1, and 1½ inch	4	....	4
Hames	2	....	2
Hame straps	3	....	3

LOADINGS OF HEADQUARTERS TOOL WAGONS—SPRING—Continued.

	Engineer regiment.		Mounted engineers, battalion headquarters.
	Regimental headquarters.	Battalion headquarters.	
Rings, $\frac{3}{4}$, 1, $1\frac{1}{2}$, and 2 inch	4	....	4
Snaps, 1, $1\frac{1}{4}$, and $1\frac{1}{2}$ inch	3	....	3
Harness accessories (furnished by the Quartermaster Corps):			
Oil, neat's foot, gallons	$\frac{1}{2}$	....	$\frac{1}{2}$
Soap, harness, pounds	1	....	1
Sponge	1	....	1
Wire, stove, spool	1	....	1
Additional supplies (furnished by the Quartermaster Corps): Shoes, mule, fitted, with 8 nails each	16	....	16

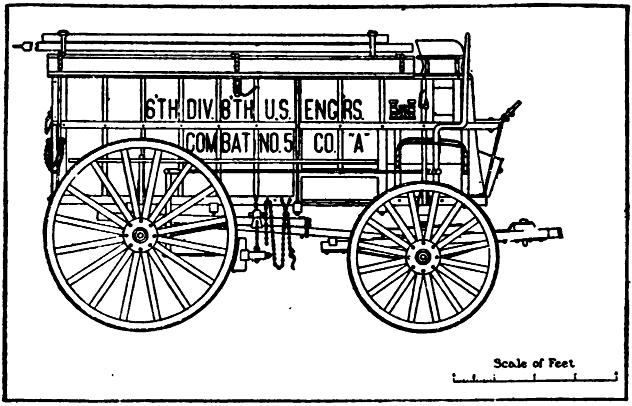


FIG. 131. COMPANY TOOL WAGON.

3. LOADINGS OF COMPANY TOOL WAGONS.

	Engineer company, regimental (one-half of quantities given below carried on each wagon).	Company of Mounted Engineers (one wagon only).
Carpenter equipment: Chest, carpenter's, containing augers, ship, handled (3); scratch awl; ax, handled, 32-inch (with extra handle); ratchet brace, and bits (2 auger, 1 expansion, 2 screw-driver); chisels, framing, handled (3), (one extra handle); cold chisel; wing dividers; draw knife; files, saw, taper (3); hammer, claw (with extra handle); ratchets (5); 24-inch carpenter's level; mallet; oiler, ½ pint; oilstone; jack-plane; pliers; plumb bob; rules, 2-foot (4); saws, hand [rip (1), crosscut (2), compass (1)]; saw set; screw driver; squares, steel, carpenter's (1), try (1); tape, metallic, 50-foot; T bevel, and wrenches, monkey, 12-inch .... sets	2	1
Carpenter's supplies:		
Chalk, carpenter's, pound	½	½
Chalk lines, 40-foot	4	2
Pencils, carpenter's, dozen	1	½
Demolition equipment:		
Augers, earth, handled, and ship, handled, 1½-inch; bars, pinch, large, and wood, tamping; cold chisel; single bit drills, long and short; miner's spoon, long (one of each) .... set	2	1

LOADINGS OF COMPANY TOOL WAGONS—Continued.

	Engineer company, regimental (one-half of quantities given below carried on each wagon).	Company of Mounted Engineers (one wagon only).
Box, cap	2	1
Box, match	2	1
Circuit detectors	2	1
Crimpers	2	1
Hammers, sledge, 8-pound	4	2
Magneto exploders	2	1
Pick mattocks, E. D. pattern, "intrenching," handled.	4	2
Shovels, E. D. pattern, "intrenching"	8	4
Spoons, miner's, long	2	1
Wire, firing, double-lead No. 14, on reel, feet	2,000	1,000
Demolition supplies:		
Caps, detonating	100	50
Explosive, pounds	200	100
Fuse, Bickford, feet	200	100
Fuse, instantaneous, feet	200	100
Fuses, electric	200	100
Matches, safety, boxes, dozen	1	½
Tape, insulating, rolls	2	1
Twine, hemp, 2-ounce balls	2	1
Drafting equipment:		
Boards, drawing, 23 by 31 inches (with trestles)	2	1
And the following equipment: Field drawing instruments (set); steel eraser; erasing shield; map measure; protractors, G. S., semicircular, 6-inch; scales, 12-inch; architect's (1) and engineer's (1); triangles, 30°–60° and 45°, and T squares, 24-inch ....set	2	1
Lamp, acetylene	2	1
Tubes, tin	6	3
Drafting supplies:		
Books, note	6	3
Carbide, in 10-pound cans, pounds	40	20
Cloth, tracing, 30-inch, roll, yards	48	24
Erasers, rubber, pencil (2), ink (1)	6	3
Ink, drawing, black (2), blue (1), carmine (1), bottles	8	4
Ink, india, stick	2	1
Pencil-pointing pad, 1¼ by 4 inches; scratch pad, 6 by 9 inches (2); blotting paper, 3¾ by 9½ inches, dozen (1); pins; adhesive tape (2 rolls) and twine (2-ounce ball) ....set	2	1
Drawing paper, 22 by 30 inches, sheets	288	144
Pencils, H and 3H (of each)	12	6
Pens, crow-quill and mapping, with holder (of each)	24	12
Thumb tacks	24	12
Hectograph equipment:		
Hectographs, clay, 20 by 24 inches	2	1
Levelers, hectograph	2	1
Sponges	2	1

LOADINGS OF COMPANY TOOL WAGONS—Continued.

	Engineer company, regimental (one-half of quantities given below carried on each wagon).	Company of Mounted Engineers (one wagon only).
Hectograph supplies:		
Ink, green (1), red (1), violet (2), bottles	8	4
Paper, book, 19 by 24 inches, quires	10	5
Miscellaneous equipment:		
Bags for nails, two 50-pound, one 100-pound	6	3
Buckets, galvanized-iron	6	3
Cans, galvanized-iron, 5-gallon	2	1
Carborundum wheels	2	1
Handles, ship-auger (1), sledge (1), hatchet (3), pick-mattock (6)	22	11
Lanterns, dark (3), Dietz (6)	18	9
Manuals, Engineer Field (12), Ponton (1)	26	13
Marlinspikes	2	1
Padlocks, brass	12	6
Stamps, steel, sets	2	1
Stencils, sets	2	1
Miscellaneous supplies:		
Canvas, 10-ounce, width 36 inches, yards	20	10
Grease, axle, pounds	10	5
Marline, pounds	36	18
Nails, 60-penny (100 pounds), 30-penny (50 pounds), 16-penny (50 pounds)	400	200
Oil, signal, gallons	10	5
Oil, machine, quarts	2	1
Staples, pounds	20	10
Screws, assorted, gross	6	3
Wicks, extra, dark lantern (6), Dietz (12)	36	18
Wire, B. & S. No. 16, pounds	50	25
Photographic equipment:		
Camera, 3A kodak	1	....
Tripod, metal, folding	1	....
And the following accessories: Rubber blankets (2); canvas buckets (2); bulb, rubber; printing frames, 5 by 7 inches (2); graduate, 8 ounces; ruby lamp; Photographer's Manual; stirring rods (2); shears 8 inches; film tank, 3½-inch; thermometer; towels, bath (4) and agate trays (4) ... set	1	....
Photographic supplies:		
Albums for 3A films, size 3¼ by 5½ inches	1	....
Books, photo note	1	....
Developer, M. Q. and Pyro, 8 boxes each, boxes	16	16
Films, 3A size, 6 exposures, size 3¼ by 5½ inches	24	24
Hypo acid, in ½-pound boxes, boxes	24	24
Paper, 3A developing, size 3¼ by 5½ inches (1 gross), printing out (1 gross), gross	2	....
And the following articles: Potassium bicarbonate, 1 pound; twine ball (2 ounces); cheesecloth, white, 3		

LOADINGS OF COMPANY TOOL WAGONS—Continued.

	Engineer company, regimental (one-half of quantities given below carried on each wagon).	Company of Mounted Engineers (one wagon only).
yards; photo clips (12); formalin, 1 pound; intensifier, tube (1); pushpins (12); potassium bromide tabloid tube (1); reducer tube (1) and wicks, ruby lamp (6) .... set	1	1
Pioneer equipment:		
Adzes, handled, 32-inch	4	2
Axes, handled, 36-inch	26	13
Bars, pinch, large	2	1
Blocks, 8-inch, double; 8-inch, single; 8-inch, snatch; and 8-inch, triple	8	4
Bolts, clippers	6	3
Climbers, lineman's, set	2	1
Comealongs	4	2
Files, crosscut saw	6	3
Hammers, sledge, handled, 8-pound	4	2
Handles, extra, adz, 32-inch; ax, 36-inch; pick, railroad, 36-inch; saw, crosscut, 1-man; and saw, crosscut, 2-man	14	7
Hatchets	6	3
Knives, Gabion	18	9
Machetes, with sheaths	36	18
Mauls, wood	4	2
Peevies, handled	4	2
Picks, railroad, handled	6	3
Pick mattocks:		
E. D. pattern, "Intrenching," handled	30	15
Large, handled	6	3
Pliers, side-cutting	18	9
Points, pike and hook	4	2
Posthole diggers	2	1
Rope, manila, 1-inch diameter .... feet	500	250
Saw, crosscut, 1-man	2	1
Saw, crosscut, 2-man	4	2
Saw, hack (with 6 blades)	2	1
Saw tools	2	1
Shovels, E. D. pattern, "intrenching"	60	30
Shovels, long-handled	12	6
Tapes, metallic, 50-foot	4	2
Wedges, steel, 5-pound	4	2
Wrenches, monkey, 18-inch	2	1
Wrenches, Stillson, 18-inch	2	1
Pioneer supplies:		
Bolts, drift, $\frac{3}{4}$-inch (40), $\frac{1}{2}$-inch (40)	160	80
Lashings, manila, $\frac{3}{4}$-inch diameter, 50-foot (12), $\frac{1}{2}$-inch diameter, 18-foot (25)	74	37
Sandbags, with binders	500	250
Tape, tracing, feet	3,000	1,500

LOADINGS OF COMPANY TOOL WAGONS—Continued.

	Engineer company, regimental (one-half of quantities given below carried on each wagon).	Company of Mounted Engineers (one wagon only).
Reconnaissance equipment:		
Chests, sketching outfit, each containing sketching board, with alidade, and folding tripod; service clinometer; timing pad holder; pencil pocket; rectangular protractor and pace tally	6	3
The following additional equipment—		
Barometer, aneroid, with cases	4	2
Clinometer, service, with cases	8	4
Compasses, box (2), prismatic, with cases (2), watch (6)	20	10
Field glasses, with cases	2	1
Odometers, with cases	2	1
Pace tallies	8	4
Protractors, rectangular	2	1
Sextants, pocket	2	1
Reconnaissance supplies:		
Books, note, field	32	16
Celluloid sheets	72	36
Erasers, rubber, pencil	28	14
Pads, timing	36	18
Paper, sketching, sheets, gross	3	$1\frac{1}{2}$
Pencils, blue (14), drawing, H (42), green (14), red (14)	168	84
Protectors, pencil-point	28	14
Tape, adhesive, rolls	12	6
Company tool wagon parts, extra (furnished by the Engineer Department):		
Bolts, king, 1 by 18 inches (1); tire, $\frac{1}{2}$ by $2\frac{3}{4}$ inches (1), and $\frac{1}{2}$ by 3 inches (5); square head, $\frac{5}{8}$ by $2\frac{1}{2}$ inches (2); carriage, $\frac{3}{8}$ and $\frac{1}{2}$ by 4 inches (2), and $\frac{1}{2}$ by 2 and $3\frac{1}{2}$ inches (4); carriage, $\frac{5}{16}$ by $3\frac{1}{2}$ inches (2) .... set	2	1
Links, open	6	3
Nuts, axle (one R. H. and one L. H.)	4	2
Reach, tongue, singletree, extra (of each)	2	1
Rivets, iron, $\frac{5}{16}$ by $2\frac{3}{4}$ inches (6) and $\frac{1}{4}$ by $2\frac{3}{4}$ inches (4).	20	10
Wrenches, axle	2	1
Company tool wagon accessories (furnished by the Quartermaster Corps):		
Nose bags, halters, and straps (of each)	8	4
Currycomb and horse brush (of each)	2	1
Grease, axle, pounds	8	4
Whips	2	1
Harness parts, extra (furnished by the Quartermaster Corps):		
Buckles, $\frac{3}{4}$, $\frac{7}{8}$, 1, and 2 inch	8	4
Clips, trace	4	2
Hames	4	2
Rings, $\frac{3}{4}$, 1, $1\frac{1}{2}$, and 2 inch	8	4
Snaps, 1, $1\frac{1}{2}$, and 2 inch	6	3
Straps, hame	6	3

LOADINGS OF COMPANY TOOL WAGONS—Continued.

	Engineer company, regimental (one-half of quantities given below carried on each wagon).	Company of Mounted Engineers (one wagon only).
Harness accessories (furnished by the Quartermaster Corps):		
Oil, neat's-foot, gallons	1	½
Soap, harness, pounds	2	1
Sponges	2	1
Wire, stove, spool	2	1
Additional supplies (furnished by the Quartermaster Corps): Mule shoes, fitted, and 10 nails	32	16

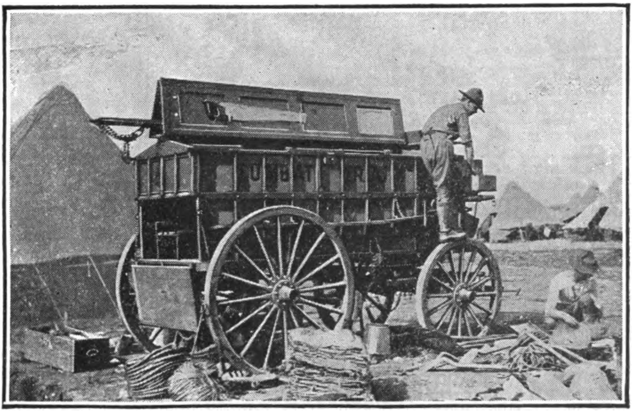


FIG. 132. COMPANY TOOL WAGON, OPEN, SHOWING EQUIPMENT.

4. PACK OUTFITS.

	Box 1-A.	Box 1-B.
PACK NO. 1, EQUIPMENT.		
Carpenters, farriers, and saddlers:		
Bag, nail, 10-pound	1	1
Bag, for small articles	1	1
Bar, pinch, small	1	1
Box, pack No. 1	1	1
Brace and bits (7 auger and 1 screw driver), hand saws, C. C. (2) ... set	1	....
Carpenter's bag; framing chisels (3); claw hammers (2); hatchets (4); 50-foot metallic tape; monkey wrench; ship augers, 1/16-inch, handled (2); side-cutting pliers (2); and steel square ... set	....	1
Hammer, sledge, 8-pound	....	1
Farrier's hammer, shoe knife (in case), nippers, pincers, shoeing rasp, 16-inch, and flat bastard file, 12-inch set,	1	....
Revolving punch, rivet set, and stitching awl ... set	....	1
Rolls, canvas, for tools	1	2
PACK NO. 1, SUPPLIES.		
Carpenter;		
Bolts, drift, ½-inch	20	20
Carpenter pencils(6), chalk, ¼-pound, chalk lines (2), set	....	1
Nails, 60-penny (10 pounds), 16-penny (10 pounds), pounds	10	10
Farrier:		
Beeswax (2 ounces), harness needles (2 papers), harness rivets, assorted (1 pound), harness thread (2-ounce ball) ... set	....	1
Nails, horseshoe, pounds	3	....
Shoes, mule, fitted	6	....
	Boxes 2-A and 3-A each contain—	Boxes 2-B and 3-B each contain—
PACKS NOS. 2 AND 3, EQUIPMENT.		
Demolition:		
Canvas bucket; cold chisel; pinch bar, small (of each)	....	1
Clasp knife; crimper; cap box; match box (of each)	1	1
Pick mattock, mining; ship auger, 1¾-inch, handled (of each)	....	1
Pliers, side-cutting	....	2
Shovels, mining; sledge (8 pounds); single-bit drill, small; miner's spoon (of each)	1	....
Roll, canvas, for tools	1	1
PACKS NOS. 2 AND 3, SUPPLIES.		
Demolition:		
Caps, detonating	50	50
Cord, detonating (2 spools), and 12 unions ... set	1	1
Explosive, pounds	45	45
Fuse, Bickford, feet	100	100
Fuse lighters, Bickford	30	30
Lashings, manila, ½-inch, 18 feet	1	1
Matches, safety, boxes	6	6
Twine, hemp, 2-ounce ball	1	1
Wire, copper, No. 30, ¼-pound spool	1	1

PACK OUTFITS—Continued.

	Box 4-A.	Box 4-B.
PACK NO. 4, EQUIPMENT.		
Pioneer equipment:		
Axes, handled, 36-inch	3	3
Boxes, pack, No. 4	1	1
Pick mattocks, handled } E. D. pattern, mining	5	5
Shovels } E. D. pattern, mining	10	10
	Box 5-A.	**Box 5-B.**
PACK NO. 5, EQUIPMENT.		
Pioneer equipment:		
Blocks—6-inch, double; 6-inch, single; 6-inch, snatch . set	3	3
Boxes, pack No. 5	1	1
Hatchets	....	2
Machetes, with sheaths	5	5
Rope, manila, ¾-inch diameter, 200-foot coils	1	1
Saws, folding, with cases	1	1
Saws, crosscut, hand, 20-inch	2	....

APPENDIX III

ORGANIZATION OF ENGINEER TROOPS

From Tables of Organization,
U. S. Army,
1917

CORRECTION TO TABLES OF ORGANIZATION

By the terms of General Order No. 85, War Department, July 9, 1917, the authorized strength of an engineer regiment was increased by 36 enlisted men, to be assigned to the headquarters detachment as follows:

First sergeant	1
Mess sergeant	1
Supply sergeant	1
Stable sergeant	1
Corporals	4
Horseshoers	2
Saddler	1
Cook	1
Privates, first class	6
Privates	18
Total	36

This makes a total regimental headquarters detachment of 76 enlisted men, and increases the maximum strength of an engineer regiment to 1097 enlisted and 37 officers, a total of 1134.

TABLE 1.—*Regiment of engineers.*

MAXIMUM STRENGTH.

1	2	3	4	5	6	7	8	9	10	11
		Battalion.			Regiment.					
Units.	Company in battalion	Headquarters	3 companies.	Total.	Headquarters.	2 battalions.	Total.	Medical Department and Chaplain.	Aggregate.	Remarks.
Colonel	......	......	......	......	1h	......	1	......	1	
Lieutenant colonel	......	......	......	......	1h	......	1	......	1	
Major	......	1h	......	1	......	2	2	......	2	
Captain	1h	1h	3	4	3h	8	11	......	11	
First lieutenant	2h	......	6	6	......	12	12	......	12	
Second lieutenant	1h	......	3	3	......	6	6	......	6	
Medical department	......	......	......	......	......	......	......	3h	3	
Chaplain	......	......	......	......	......	......	......	1h	1	
Total commissioned	4	2	12	14	5	28	33	4	37	
Master engineer, senior grade	......	......	......	......	4h	......	4	......	4	a 2 wagons of small-arms ammunition per battalion march ordinarily with the divisional engineer train.
Master engineer, junior grade	......	6h	......	6	......	12	12	......	12	
Regimental sergeant major	......	......	......	......	1h	......	1	......	1	
Regimental supply sergeant	......	......	......	......	2h	......	2	......	2	
Battalion sergeant major	......	1h	......	1	......	2	2	......	2	
First sergeant	1	......	3	3	......	6	6	......	6	
Sergeant, first class	3 1h	......	9	9	......	18	18	......	18	

Sergeant bugler	......	......	......	......	1[h]	......	1	......	1
Color sergeant	......	......	......	......	2	......	2	......	2
Supply sergeant	1	......	3	3	......	6	6	......	6
Mess sergeant	1	......	3	3	......	6	6	......	6
Stable sergeant	1[h]	......	3	3	......	6	6	......	6
Sergeant	8[2h]	......	24	24	2 t	48	50	......	50
Corporal	18[4h]	......	54	54	......	108	108	......	108
Horseshoer	1[h]	......	3	3	......	6	6	......	6
Saddler	1	......	3	3	......	6	6	......	6
Wagoner	[b]*4*	[b]*7*	[b]*6*	......	27	......	27	......	27
Cook	3 [1h]	......	9	9	1	18	19	......	19
Bugler	2 [1h]	......	6	6	......	12	12	......	12
Private, first class	31 [8h]	......	93	93	......	186	186	......	186
Private	93 [17h]	......	279	279	......	558	558	......	558
Medical department	......	......	......	......	......	......	......	23 [10h]	23
Total enlisted	164	7	492	499	40	998	1,038	23	1,061
Aggregate	168	9	504	513	45	1,026	1,071	27	1,098
Combat train[a]	[b]*2*	[b]*1*	[b]*6*	[b]*7*	16	......	16	......	16
Field train, ration	[b]*1*	[b]*4*	......	[b]*4*	8	......	8	......	8
Field train, baggage	[b]*1*	[b]*2*	......	[b]*2*	3	......	3	......	3
Total wagons	......	......	......	......	27	......	27	......	27
Horses, riding	40	10	120	130	17	260	277	15	292
Mules, pack	8	......	24	24	......	48	48	1	49
Mules, draft	[b]*16*	[b]*28*	[b]*24*	[b]*52*	112	......	112	......	112
Total mules	8	......	24	24	112	48	160	1	161
Rifles	158	......	474	474	30	948	978	......	978
Pistols	52	9	156	165	18	330	348	......	348
Net length, yards	112	......	......	361	......	......	......	......	816
+ Combat train	136	......	......	445	......	......	......	......	1,008
+ Field train	160	......	......	517	......	......	......	......	1,140

[b] Assigned to companies and battalions from headquarters detachment and accompany them when detached. Totaled in headquarters of the regiment. Combat wagons are furnished by the Engineer Department and are permanently assigned to companies and battalions.

[h] Mounted.

TABLE 2.—*Regiment of engineers.*

MINIMUM STRENGTH.

1	2	3	4	5	6	7	8	9	10	11
		Battalion.			Regiment.					
Units.	Company in battalion	Headquarters.	3 companies.	Total.	Headquarters.	2 battalions.	Total.	Medical Department and Chaplain.	Aggregate.	Remarks.
Colonel	......	......	......	......	1 h	......	1	......	1	
Lieutenant colonel	......	......	......	......	1 h	......	1	......	1	
Major	......	1 h	......	1	......	2	2	......	2	
Captain	1 h	1 h	3	4	3 h	8	11	......	11	
First lieutenant	2 h	......	6	6	......	12	12	......	12	
Second lieutenant	1 h	......	3	3	......	6	6	......	6	
Medical department	......	......	......	......	......	......	......	3 h	3	
Chaplain	......	......	......	......	......	......	......	1 h	1	
Total commissioned	4	2	12	14	5	28	33	4	37	
Master engineer, senior grade	......	......	......	......	2 h	......	2	......	2	
Master engineer, junior grade	......	3 h	......	3	......	6	6	......	6	a 2 wagons of small-arms ammunition per battalion march ordinarily with the divisional engineer train.
Regimental sergeant major	......	......	......	......	1 h	......	1	......	1	
Regimental supply sergeant	......	......	......	......	2 h	......	2	......	2	
Battalion sergeant major	......	1 h	......	1	......	2	2	......	2	
First sergeant	1	......	3	3	......	6	6	......	6	
Sergeant, first class	3 1h	......	9	9	......	18	18	......	18	

Sergeant bugler	......	......	......	......	1 [h]	......	1	......	1
Color sergeant	......	......	......	......	2	......	2	......	2
Supply sergeant	1	......	3	3	......	6	6	......	6
Mess sergeant	1	......	3	3	......	6	6	......	6
Stable sergeant	1 [h]	......	3	3	......	6	6	......	6
Sergeant	6 [1h]	......	18	18	......	36	36	......	36
Corporal	12 [7h]	......	36	36	......	72	72	......	72
Horseshoer	1 [h]	......	3	3	......	6	6	......	6
Saddler	1	......	3	3	......	6	6	......	6
Wagoner	[b] *4*	[b] *7*	[b] *6*	......	27	......	27	......	27
Cook	2	......	6	6	1	12	13	......	13
Bugler	2 [1h]	......	6	6	......	12	12	......	12
Private, first class	19 [6h]	......	57	57	......	114	114	......	114
Private	59 [10h]	......	177	177	......	354	354	......	354
Medical department	......	......	......	......	......	......	......	15 [11h]	15
Total enlisted	109	4	327	331	36	662	698	15	713
Aggregate	113	6	339	345	41	690	731	19	750
Combat train [a]	[b] *2*	[b] *1*	[b] *6*	[b] *7*	16	......	16	......	16
Field train, ration	[b] *1*	[b] *4*	......	[b] *4*	8	......	8	......	8
Field train, baggage	[b] *1*	[b] *2*	......	[b] *2*	3	......	3	......	3
Total wagons	......	......	......	......	27	......	27	......	27
Horses, riding	28	7	84	91	13	182	195	15	210
Mules, pack	8	......	24	24	......	48	48	1	49
Mules, draft	[b] *16*	[b] *28*	[b] *24*	[b] *52*	112	......	112	......	112
Total mules	8	......	24	24	112	48	160	1	161
Rifles	103	......	309	309	28	618	646	......	646
Pistols	39	6	117	123	13	246	259	......	259
Net length, yards	110	......	......	350	......	......	......	......	750
+ Combat train	134	......	......	434	......	......	......	......	942
+ Field train	158	......	......	506	......	......	......	......	1,074

[b] Assigned to companies and battalions from headquarters detachment and accompany them when detached. Totaled in headquarters of the regiment. Combat wagons are furnished by the Engineer Department and are permanently assigned to companies and battalions.

[h] Mounted.

Table 3.—*Battalion of mounted engineers.*

Maximum Strength.

1	2	3	4	5	6	7	8
		Battalion.					
Units.	Company in battalion.	Headquarters.	3 companies.	Total.	Medical department.	Aggregate.	Remarks.
Major	.....	1	.....	1	.....	1	
Captain	1	2	3	5	.....	5	
First lieutenant	2	1	6	7	.....	7	
Second lieutenant	1	.....	3	3	.....	3	
Medical department	.....	.....	.....	.....	2	2	
Total commissioned	4	4	12	16	2	18	
Master engineer, senior grade	.....	2	.....	2	.....	2	
Master engineer, junior grade	.....	6	.....	6	.....	6	
Battalion sergeant major	.....	1	.....	1	.....	1	
Battalion supply sergeant	.....	1	.....	1	.....	1	
First sergeant	1	.....	3	3	.....	3	[a] 2 wagons of small-arms ammunition per battalion march ordinarily with the divisional engineer train.
Sergeant, first class	2	.....	6	6	.....	6	
Supply sergeant	1	.....	3	3	.....	3	
Mess sergeant	1	.....	3	3	.....	3	
Stable sergeant	1	.....	3	3	.....	3	
Sergeant	6	2	18	20	.....	20	

Corporal	11	1	33	34	......	34
Horseshoer	2	......	6	6	......	6
Saddler	1	......	3	3	......	3
Wagoner	[b] *4*	12	......	12	......	12
Cook	2	......	6	6	......	6
Bugler	2	......	6	6	......	6
Private, first class	20	......	60	60	......	60
Private	61	......	183	183	......	183
Medical department	......	......	......	......	11	11
Total enlisted	111	25	333	358	11	369
Aggregate	115	29	345	374	13	387
Combat train [a]	[b] 1	5	......	5	......	5
Field train, ration	[b] 2	5	......	5	......	5
Field train, baggage	[b] 1	2	......	2	......	2
Total wagons	......	12	......	12	......	12
Horses, riding	115	18	345	363	13	376
Mules, pack	12	......	36	36	1	37
Mules, draft	[b] *16*	52	......	52	......	52
Total mules	12	52	36	88	1	89
Rifles	106	15	318	333	......	333
Pistols	115	17	345	362	1	363
Net length, yards	140	......	......	460	......	460
+ Combat train	152	......	......	520	......	520
+ Field train	......	......	......	604	......	604

[b] Assigned to companies and battalions from headquarters detachment and accompany them when detached. Totaled in headquarters of the battalion. Combat wagons are furnished by the Engineer Department and are permanently assigned to companies and battalions.

TABLE 4.—*Battalion of mounted engineers.*

MINIMUM STRENGTH.

1	2	3	4	5	6	7	8
Units.	Company in battalion.	Battalion.					Remarks.
		Headquarters.	3 companies.	Total.	Medical Department.	Aggregate.	
Major	.....	1	.....	1	.....	1	
Captain	1	2	3	5	.....	5	
First lieutenant	2	1	6	7	.....	7	
Second lieutenant	1	.....	3	3	.....	3	
Medical department	.....	.....	.....	.....	2	2	
Total commissioned	4	4	12	16	2	18	
Master engineer, senior grade	.....	1	.....	1	.....	1	
Master engineer, junior grade	.....	3	.....	3	.....	3	
Battalion sergeant major	.....	1	.....	1	.....	1	
Battalion supply sergeant	.....	1	.....	1	.....	1	
First sergeant	1	.....	3	3	.....	3	[a] 2 wagons of small-arms ammunition per battalion march ordinarily with the divisional engineer train.
Sergeant, first class	2	.....	6	6	.....	6	
Supply sergeant	1	.....	3	3	.....	3	
Mess sergeant	1	.....	3	3	.....	3	
Stable sergeant	1	.....	3	3	.....	3	
Sergeant	4	.....	12	12	.....	12	

Corporal	8	1	24	25	......	25
Horseshoer	2	......	6	6	......	6
Saddler	1	......	3	3	......	3
Wagoner	[b] *4*	12	......	12	......	12
Cook	2	......	6	6	......	6
Bugler	2	......	6	6	......	6
Private, first class	12	......	36	36	......	36
Private	37	......	111	111	......	111
Medical Department	......	......	......	......	7	7
Total enlisted	74	19	222	241	7	248
Aggregate	78	23	234	257	9	266
Combat train [a]	[b] 1	5	......	5	......	5
Field train, ration	[b] 2	5	......	5	......	5
Field train, baggage	[b] 1	2	......	2	......	2
Total wagons	......	12	......	12	......	12
Horses, riding	78	12	234	246	11	257
Mules, pack	12	......	36	36	1	37
Mules, draft	[b] *16*	52	......	52	......	52
Total mules	16	52	36	88	1	89
Rifles	69	13	207	220	......	220
Pistols	78	11	234	245	1	246
Net length, yards	95	......	......	316	......	316
+ Combat train	107	......	......	376	......	376
+ Field train	......	......	......	460	......	460

[b] Assigned to companies and battalions from headquarters detachment and accompany them when detached. Totaled in headquarters of the battalion. Combat wagons are furnished by the Engineer Department and are permanently assigned to companies and battalions.

TABLE 5.—*Trains—Infantry Division—Engineer.*

MAXIMUM AND MINIMUM STRENGTH.

1	2	3	4	5	6
Units.	Headquarters and supply section.	Searchlight section.	[a] Ponton section.	Total.	Remarks.
Captain	1 [h]	....	....	1	
First lieutenant	....	1 [h]	1 [h]	2	
Second lieutenant	....	1 [h]	....	1	
Total commissioned	1	2	1	4	
Master engineer, senior grade	....	2 [h]	....	2	[a] 2 heavy (wooden) bridge divisions, each capable of making 225 feet of normal bridge for vehicles weighing up to 6,000 pounds, or 150 feet of bridge with close intervals for vehicles up to 12,000 pounds.
Master engineer, junior grade	....	4 [h]	....	4	
First sergeant	1 [h]	....	....	1	
Sergeant, first class	....	2	....	2	
Battalion supply sergeant	1 [h]	....	....	1	
Supply sergeant	....	1 [h]	1	2	
Stable sergeant	....	1	1	2	
Sergeant	....	4	2 [h]	6	
Corporal	2 [h]	4	4 [h]	10	
Horseshoer	1	1	3	5	[b] 10 wagons carrying tools, 1 wagon for each Infantry and Cavalry regiment, and 4 wagons carrying small arms ammunition for Engineer regiment.
Saddler	....	....	1	1	
Wagoner	33	20	37	90	
Cook	1	1	1	3	
Bugler	1 [h]	1 [h]	1 [h]	3	
Private, first class	12	8	....	20	
Private	....	14	....	14	
Total enlisted	52	63	51	166	[c] Number based on the following equipment: 6 power units, 6 searchlight units, 3 tool and supply wagons,
Aggregate	53	65	52	170	

Combat train, wagons	[b] 14	[c] 18	30	62	and 3 trench-light wagons with batteries and flares; all 4-mule wagons. Number will vary with change in type of equipment.
Field train, wagons	1	1	2	4	
Technical supply train, wagons	4	....	4	8	
Motor trucks	12	1	....	13	
Motor cars	2	....	....	2	
Motor cycles, with side cars	....	3	....	3	
Horses, riding	6	10	8	24	
Mules, draft	80	76	190	346	
Rifles	49	54	50	153	
Pistols	6	17	10	33	
Net length, yards	....	....	....	1,500	